PANEL
USE OF AERIAL PHOTOGRAPHS FOR CADASTRAL SURVEYS

MODERATOR
Mr. Daniel Kennedy

PARTICIPANTS

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Foreword

JOE STEAKLEY,
Convention Program Chairman

This Panel Meeting was held at the St. Louis Semi-Annual, Joint Meeting of the American Society of Photogrammetry and the American Congress on Surveying and Mapping on 14 September 1962. Congratulations are due Mr. Jerome T. Berry, U. S. G. S., Central Area, Rolla, Missouri, for contributing his administrative and technical talent to all the necessary details before, during, and after this meeting. The meeting was well received, and it provoked interesting new material for our profession.

INTRODUCTION OF MODERATOR BY JEROME T. BERRY

Introducing Mr. Daniel Kennedy the Moderator is a pleasure.

Mr. Kennedy is the Central Region Engineer of the Topographic Division, U. S. G. S., Rolla, Mo. He has been associated with that agency since 1926, except for four years when he served with Patton's Third Army in World War II, a period as Chief Topographic Engineer, Army Map Service, 1946–47, and as Deputy Engineer, Task Force Seven, the Eniwetok A-Bomb experiments, in 1948. In May, 1948, he returned to the U.S.G.S. as Region Engineer, Central Area. From the Missouri School of Mines and Metallurgy Mr. Kennedy received the degree of BSCE in 1932, Civil Engineering in 1935, and Doctor of Engineering (honoris causa) in 1949. He was given the Department of the Interior Distinguished Service Award in 1961. He is a Registered Professional Engineer in the State of Missouri, and a member of the American Society of Civil Engineers, American Society of Photogrammetry, American Congress on Surveying and Mapping, American Military Engineers, National and Missouri Societies of Professional Engineers, Sigma Xi, and Chi Epsilon. He is author of approximately fifty Geological Survey Topographic maps.

INTRODUCTION OF FIRST SPEAKER BY THE MODERATOR

It is a pleasure to serve as Moderator of this Panel.

The first speaker is Mr. James McMurry Anderson.

Mr. Anderson is a part-time teacher, and operator of the Wild A-7 Autograph, in the Surveying Department of Cornell University, where he is studying for his Ph.D., majoring in Photogrammetry. He received his B.S. degree in Civil Engineering from the University of Pittsburgh in 1949. From then until June, 1956, he was employed by H. A. Shope, Professional Engineer and Land Surveyor, Homestead, Pennsylvania, during which period he became registered as a Surveyor and Professional Engineer in Pennsylvania. He worked with Richardson-Gordon & Associates, Consulting Engineers in Pittsburgh until 1958, when he entered the Graduate School at Cornell University, receiving his Master's degree in 1959.

Accuracy of Planimetric Positions Determined from Large-Scale Photography

JAMES M. ANDERSON,
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Ithaca, N. Y.

During recent years much attention has been focussed on the use of photogrammetric methods in connection with cadastral surveys.

One of the chief questions concerns the obtainable accuracy.

That photogrammetric measurements, made with first-order instruments, are sufficiently accurate for cadastral surveys has been well established. In experiments in Germany, Switzerland, Netherlands and Canada, ample evidence has been furnished concerning the accuracy of photogrammetric measurements for cadastral surveys.[1,2,3] In the United States, such methods have been applied to practical cadastral problems by the U. S. Forest Service and the U. S. Bureau of Land Management.[4,5] However, each application of photogrammetry to property surveys had certain common characteristics: control points, property corners and test points were pre-marked with targets; the photography scale varied from 1/6,000 to 1/10,000; and the areas from 1,000 acres to 2,000 acres.

Many land surveyors in the U. S. do most of their work in developments containing from 30 to 200 acres. For their work a more realistic evaluation of photogrammetry would be provided by a test project through using low-altitude photography taken over a relatively small area and containing no pre-marked control points.

In conducting the test project, the instrument coordinates of 50 points were determined in a single stereoscopic model covering an area of approximately 60 acres. A first-order instrument—the Wild A-7 Autograph—was used to determine the instrument coordinates. The photography was taken from a height of about 1,400 feet above ground elevation. The control points were not pre-marked. The objectives of the investigation were as follows:

1. To make a comparison of the coordinated positions of points determined by photogrammetric methods with their locations obtained by traditional ground survey methods.
2. To compare the lengths of lines determined photogrammetrically with the lengths of the same lines measured on the ground.
3. To evaluate the quality of the points chosen for location and to select the most suitable type of point for this purpose.
4. To evaluate the accuracy possible in determining the position, by photogrammetric methods, of points in large-scale photography. The points so located were not pre-marked with targets.

Emphasis should be placed on the fact that none of the points used is a property corner, nor was any attempt made to determine the property lines. The primary purpose was to evaluate the accuracy possible under the cited conditions.

TEST AREA

The test area is located on the Cornell Campus at Ithaca. It was chosen because of the availability of aerial photography and the wealth of points well-defined on the ground and also identifiable in the photographs. University facilities consisting of medium-sized buildings from two to six stories high make up most of the structures in the area. Four primary streets pass through the area and numerous sidewalks and utilities are visible in the photographs. The photography was taken late in May so the leaves had started to be a problem. The land slopes uniformly from east to west with the total relief amounting to about 100 feet. The area of the portion of the campus studied is approximately 60 acres.

Photography

The photography was taken by the USC & G.S. using a Wild RC-8 Aerial Camera equipped with an Aviogon lens (f = 152.29 mm. 9″×9″ exposure). The scale is approximately 1:2,800 or 1 inch to 240 feet. Standard contact-printed Kelsh diapositive plates 5 mm. thick were used for the photogrammetric operation.

PROCEDURE

The steps necessary to complete the project may be divided into four major groups:

1. Selection of points to be located.
2. Acquisition of ground control points and the location of test points.
3. Determination of the point locations by photogrammetric methods.
4. Evaluation of the results.

Each of the above will be discussed separately.

Selection of the Points to be Located

A preliminary examination was made of the stereo model in the A-7 to aid in selecting a more suitable group of test points. Although this resulted in additional work on the A-7 it was very beneficial. The examination of the points in the stereo model made possible a much better evaluation of the type most suitable for accurate pointing. The experience gained from this project indicates that selecting points from the photographic prints is extremely difficult. Examination of the diapositive plates with the same amount of magnification as will be used for the instrumental work, provides the best selection of points.

Points were chosen that could be positively identified in both the photograph and on the ground. Examples of the selected types of points are: the intersecting edges of sidewalks, joints in the sidewalks; intersecting curbs at the face of the curb, its back or its center line; corners of concrete platforms; corners of the cast iron grate inlets; and the center lines of intersecting painted stripes used to mark parking spaces. Although an attempt was made to use only points on the ground level quite a few points were chosen on the corners of walls. An evaluation of the quality of the points selected will be made later.

Acquisition of Ground Control Points

The primary control survey was established by transit and tape traverse with an accuracy of one part in 10,000. To locate the desired number of test points it was necessary to establish supplementary traverses. Such traverses were run with an accuracy of not less than one part in 8,000. All traverse computations were performed on the electronic computer at the Cornell Computing Center.

In locating the test points, individual points were included either as a traverse point in one of the supplementary traverses, or the point was located from the supplementary traverse by a closed traverse. In this way a check on every test point was available on both field work and computations.

Elevations of test points were determined by closed-circuit differential leveling. Each control elevation was included as a turning point in the closed level circuit.

Photogrammetric Measurements

The photogrammetric phase of the problem may be divided into three sections:

1. The relative and absolute orientation of the stereoscopic model.
2. Determination of the instrument coordinates of the points previously selected.
3. Transformation of instrument coordinates to ground coordinates.

All photogrammetric measurements were performed on the Wild A-7 in the School of

Civil Engineering Surveying Department at Cornell University. The computations necessary for coordinate transformation were made with the Burroughs 220 Electronic Computer at the Cornell Computing Center.

Relative and Absolute Orientation

During the early stages of the project, correction plates to compensate for camera lens distortion were not available for the A-7 at Cornell. After the first set of instrument coordinates had been recorded, a set of Aviogon correction plates was obtained. Subsequently, another absolute orientation was made, and a second set of instrument coordinates was recorded. Consequently, the results evaluated in this report are based on instrument coordinates obtained from two separate absolute orientations: the first, referred to as Test 1, was made without correction for camera lens distortion; the second, referred to as Test 2, was made using the correction plates to compensate for that distortion. Although the lens distortion in the Aviogon lens is very small (± 5 microns), using the correction plates was later found to be essential for the most accurate results.

In the first absolute orientation five vertical control points and four horizontal points were used for leveling and for scaling the model. The same procedure was followed in the second orientation except that an additional horizontal control point was used for scaling.

Instrument Coordinates

The A-7 at Cornell is equipped with an EK-3d Electrical Coordinate Printer. This equipment allows rapid, accurate tabulation of instrument coordinates with a minimum effort.

In the initial test, each point was located by setting the floating dot on the point five times in succession, with the mean value being used for the transformation. This procedure seemed time-consuming without a commensurate increase in the accuracy. In the second test each point was located twice by two independent observations. The mean value of the two observations was used for the coordinate transformation.

Coordinate Transformation

A linear transformation of instrument coordinates was performed by using the following equations:

$$X = Ax + By + X_0$$
$$Y = X_0 + By + Y_0$$

where:

X & Y = the ground coordinates of a given part

x & y = the instrument coordinates of the same point

X_0 & Y_0 = translation in the X and Y directions

A, B, C and D = transformation constants representing a rotation and a change in scale.

Using two or more ground control points, the above equations are solved by the method of least squares for the transformation constants A, B, C and D and the translations X_0 and Y_0. With these constants, the ground coordinates for point i, instrument coordinates x_i & y_i may be determined.

The transformation equations were programmed for the electronic computer. Using this program in conjunction with the electrical coordinate printer, minimizes the chance of errors occurring in the computation of ground coordinates of points.

As an indication of the accuracy of the absolute orientation, the standard error of the position of the ground points used for the transformation was computed. These errors are tabulated herein for the two absolute orientations.

Test	*Standard Error Ft. On the Ground*	*Number of Control Points*
1	0.30	4
2	0.23	5

The standard error in both cases is somewhat larger than is desirable for this type of work. However, with only four or five control points, a very small error in the photo or ground coordinate of just one control point could cause the standard error to become large and still not adversely affect the location of the majority of the points in the model.

EVALUATION OF RESULTS

The results of comparing coordinates determined by photogrammetric methods and ground survey methods are tabulated in Table I. For the evaluation the standard

TABLE I

Test	*No. of Points*	*dx, ft.*	*dy, ft.*	*Maximum Errors in Ft.*	
				X	*Y*
1	43	0.25	0.47	0.70	0.96
2	51	0.32	0.23	0.67	0.43

errors were computed for the differences in X and Y coordinates according to the following formulae:

$$\text{Standard Error in the } X \text{ direction} = dx = \sqrt{\frac{v^2}{(n-1)}}$$

$$\text{Standard Error in the } Y \text{ direction} = dy = \sqrt{\frac{v^2}{(n-1)}}$$

n = number of test point
v = residual error between X ground and X transformed

In Test 1, 43 points were located by both methods. The standard errors in X and Y respectively, were 0.25 ft. and 0.47 ft. Maximum errors were 0.70 ft. in X and 0.96 ft. in Y. Correction plates to compensate for camera lens distortion were not used in this test.

Fifty-one points were compared in Test 2. Correction plates were employed to compensate for camera lens distortion in this test. The standard errors in X and Y were 0.32 ft. and 0.23 ft., respectively. The maximum errors were 0.67 ft. in X and 0.43 ft. in Y.

Care should be exercised not to interpret the results of Table 1 as an indication of the absolute accuracy of the photogrammetric method. Errors occur in the coordinates determined by ground methods as well as in the locations measured photogrammetrically. Since position determined by ground methods is normally accepted as a standard if the work meets the accuracy required for the job, then the results in Table 1 may be interpreted as an indication of correspondence.

Comparison of Length Measured Photogrammetrically and on the Ground

Table II shows the standard errors resulting from comparing lengths measured on the ground with those calculated from coordinates determined by ground survey methods. The standard error resulting from these comparisons varies from 0.13 ft. in 10 distances of from 18 to 50 feet in length to 0.18 ft. in distances from 150 to 200 feet in length. Since the errors in distances measured on the ground tend to become larger with increased length of line, the distances which were compared were divided into groups of increasing length. The comparison of lengths was made only for Test 2.

If one assumes that distances of 50 feet or less can be determined with near-absolute accuracy on the ground, then the above comparison could be considered to be a more realistic indication of the absolute accuracy of the photogrammetric method.

TABLE II

Length of Line Ft.	*Number of Lines*	*Standard Error Feet*	*Maximum Error Feet*
0–50	10	0.13	0.25
50–100	10	0.15	0.25
100–150	10	0.15	0.28
150–500	12	0.18	0.38
500–1,200	10	0.13	0.25

One would normally expect that discrepancies occurring in a comparison of distances, determined by the two methods, would become greater with increases in length of line. One reason for such an increase would be the larger accumulation of errors in the measured distance of the longer line on the ground. Another source of error would be due to the accumulation of errors inherent in the photogrammetric method. The latter group of errors would be particularly evident in the photogrammetric determination of very long lines occurring in a strip of aerial photography. On the other hand, in a single stereoscopic model, the discrepancies in the relative positions of photogrammetrically determined points should be fairly constant when using large-scale photography in which compensation for lens distortion has been made. Although the sample of comparisons obtained in this study is small, the results as shown in Table II appear to verify the above conclusion.

Evaluation of the Quality of the Points Selected

In order to arrive at some conclusion with regard to the type of points giving the best results, computation was made of the standard errors of groups of the types of points occurring most frequently. The points were divided into three principal categories: (1) sidewalk intersections and corners; (2) corners of inlet grates; and (3) corners of walls. The remainder of the points fell into groups too small to be useful for analysis. A summary of the results obtained in analyzing the above three groups is given in Table III.

Although the number of points in each category provides a rather small sample for analysis, certain conclusions can be drawn: (1) points having relief (the corners of walls) provided the least satisfactory results; (2) well-defined points at ground elevation and having the darker tones of grey brought the best results. For example, it was originally thought that the intersecting edges of side-

TABLE III

Type of Point	No. Points	Standard Error (ft.)		Maximum Error (ft.)	
		dx	dy	X	Y
Corners & Intersecting Edges of Sidewalks	19	0.19	0.30	0.43	0.61
Corners of Inlets	11	0.22	0.23	0.44	0.26
Corners of Walls	12	0.31	0.38	0.48	0.58

walks would furnish the best targets. However, the light tone of the concrete created glare that apparently reduced the pointing accuracy. The corners of inlet grates have darker tones and provided more accurate results. On the basis of the tabulated results in Table III, one can conclude that the most desirable points would have the darker tones and be located at ground elevation on relatively level terrain.

CONCLUSIONS

A comparison of coordinated positions of 51 points determined by photogrammetrical methods and traditional ground survey methods resulted in standard errors of 0.32 feet in the X coordinates and 0.23 feet in the Y coordinates. As indication of the accuracy of distance measurement, 50 distances ranging in length from 18 to 1,300 feet were calculated from photogrammetrically determined coordinates and compared to the same distances measured on the ground. This comparison resulted in standard errors varying from 0.13 to 0.18 feet.

To gain a picture of what order of accuracy the photogrammetric survey would yield, the size of the stereo model must be considered. In the photography used for this study, the dimensions of the area on the ground which can be considered usable are approximately 2,000 feet in the east-west (X) direction and about 1,300 feet in the north-south (Y) direction. Using the standard errors given above as the basis for accuracy, the coordinates of points could be determined with an accuracy of one part in 6,000 in the east-west direction and one part in 5,600 in the north-south direction.

Thus, the accuracy possible in determining the position of points by photogrammetric methods using large-scale photography, when no points have been pre-marked, is between 0.2 and 0.3 of a foot in position and between 0.1 and 0.2 of a foot in distance.

In order to achieve this accuracy certain conditions must be met:

1. The area photographed must contain sufficient well-defined points that may be identified in the field and in the photography.
2. Correction plates to compensate for residual lens distortion should be used.
3. Care should be exercised to establish the primary survey used to locate ground control points for absolute orientation, with an accuracy sufficient to provide the desired accuracies in the photogrammetric location.
4. Points chosen for location should be carefully chosen. Features having darker tones and those at ground elevation provide the most accurate locations.

To increase the accuracy, targets should be employed for point locations used for absolute orientation of the stereo model. Signalization of all utilized points whenever possible would certainly improve the accuracy. However, the results obtained in this project using a single stereo model of large-scale photography, indicate that planimetric positions of non-signalized points can be determined photogrammetrically with accuracies of between one part in 5,000 and one part in 6,000.

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MODERATOR KENNEDY:

Dr. Clair V. Mann, Civil Engineer and educator, is the next speaker. He has been Engineer of Highways, Phelps County, Missouri, since 1951. He received his B.S. degree from the University of Colorado, and a Ph.D. in Engineering Education from Iowa State University. After extensive experience as a surveying and mining engineer, he joined the faculty of the Missouri School of Mines and Metallurgy, University of Missouri, where from 1920 to 1946 he was with Department of Engineering Drawing, serving as Head of the Department and Chairman of the Committee on Engineering Education. He is the author of "Objective-Type Tests in Engineering Education," published in 1930.

Dr. Mann has served as Chairman of the Drawing Division and on the committee on administration of tests to engineering students of the American Society for Engineering Education; he is also a member of the American Congress on Surveying and Mapping and the National Society of Professional Engineers.

The Case for Adoption of Photogrammetric Methods in Land Surveying

DR. CLAIR V. MANN,
Phelps County, Surveyor,
Rolla, Mo.

THE questions for discussion are (1) whether or not we endorse photogrammetry for use in land surveying; (2) whether conventional transit-tape methods, or photogrammetric methods cost less and (3) whether photogrammetry will yield the requisite measure of accuracy.

I presume my place on the panel grew out of my recent connection as County Surveyor with the use of aerial survey methods on a Dependent Corner Restoration Survey of a six-mile square area—Township 36 North, Range 9 West, in Phelps County, Missouri.

First of all, the topographic nature of the area re-surveyed was typical Ozark hill country, consisting of rolling and often steep hills lying between sea-level elevations of 750 and 1,150 feet. The area is cut by two important spring-fed trout streams, averaging 20 to 30 feet in width, but of non-navigable nature. The area is also cut by numerous steeply sloping ravines.

As described in papers by Mr. King* and Mr. Fassett,† the Forest Service manages many millions of acres of forest land within the United States. It became interested in developing a speedy, comprehensive, accurate method of re-establishing lost or destroyed Federal Land survey section corners, so that the boundaries of these huge possessions could be quickly, accurately and economically determined and could be marked. In order to test aerial methods the Forest Service set up trial projects—one in Mississippi, a second in Minnesota, and a third in the Lake Tahoe area of Nevada and California. While general methods were developed in these three projects, a further and more definite and precise procedure was desired. After a very considerable search desired conditions were found in Phelps County.

The first contacts between Forest Service engineers and the author were on August 10, 1956. By December 11 the definite support and cooperation of Phelps county officials had been pledged. The project planning took

* PHOTOGRAMMETRIC ENGINEERING, June 1957. Also at 18th Annual Meeting of ACSM.

† Delivered at June 14, 1958 meeting of Missouri Assoc. of Registered Land Surveyors.

considerable time to mature, so that actual work was not started until November 13, 1957. The decision had been made to do the primary field work by using photogrammetric methods—augmenting that by the necessary ground work of identifying corners and constructing targets for aerial photographic fixation. The field work was finally finished by May 18, 1959.

Those in charge of the project were fully qualified for the work to be done. Mr. King for many years had been engaged in executing extended cadastral surveys, and was expert in applying photogrammetry to such work. Mr. Fassett had spent many years in precise triangulation work for the Coast Survey and U.S.G.S. networks, and had been and is Chief Cartographer for the Forest Service with headquarters at Milwaukee, Wisconsin. The author had taught astronomy, geodesy and higher surveying to senior engineering classes and for years (since 1903) had practised general civil and mining engineering, and had spent years as a United States Mineral Surveyor in Colorado, Nevada and California.

The first step in the field work was positive identification of all possible corners of the original Government Survey of the township (T.36N., R.9W); this survey was made in the years 1822–23—or 135 years before present work. To facilitate office and field operations, each of the 133 government corners was given a definite individual number. Corner No. 1 was the northeast corner of the township (and of Sec. 1). Corners 2 to 13 included all full sectional and all quarter corners, numbered in succession to the west from corner No. 1 to No. 13 which was the northwest corner of the township. Corners Nos. 14 to 20 included the string of "quarter corners" from west to east, across the center lines of sections 6 to 1. Corners 21 to 33 extended in successive order along the south lines of sections 1 to 6 inclusive. A somewhat similar pattern was adopted for identifying each of the 1/16 sectional corners whose location governed boundary lines of Forest Service lands. These corners were numbered from 201 to 326.

It seems appropriate to discuss the value and use of previously made aerial photographs, in the recovery of the corners that we wanted to find and authenticate. The area had been "flown" in 1955 for the Agricultural Stabilization and Conservation Service U. S. Department of Agriculture. These aerial photos were 9×9 inches and on a scale of 1:24,000. Before going into the field, Mr. King, by observing positions of swamped sectional lines, field corners, tree rows, and so on, was able to mark, on these photographs, and for every one of the 36 sections of the township, the exact and approximate locations of all of the full and quarter section corners, and also of many of the 1/16 corners wanted. Quarter-inch squares were drawn around full sections corner locations, and quarter-inch circles for 1/16 corners.

These existing aerial photos proved to be of the utmost use and convenience in spotting the general location of all corners. Where roads led through forests to the corner vicinity, they could be followed either with ordinary passenger car or by jeep. Frequently we walked, and followed positively identifiable ravines or ridges to the corner point. Often the photos showed open fields near corners. Mr. King used these photos almost exclusively for spotting every corner of the project—and in only two instances did he fail to get within 50 yards of his goal.

The County Surveyor's prime part in the field work was, first, to comb every record in his office, or any other, that pertained to any desired corner. This search included not only the County Surveyor's own records—but also those of the original Government Survey. A third source of records was the file of the Forest Service Rangers.

I am confident that the Moderator will not object if I insert here a plug for his excellent topographic maps. As an engineer, I was more familiar with using a topographic map than aerial photos. So, in addition to the aerial pictures, I cut some of Dr. Kennedy's topographic maps into such strips as would cover the area we were working in—and of a size that I could fold and paste inside one of our small field notes.

These maps were to a scale of 1:24,000, or roughly 3 inches per mile. The sectional lines were printed in red—and of course the maps showed all roads, streams, houses and other topographic features. To make spotting the various 1/16 corners possible, I drew on the strip topographic map the necessary lines for subdividing each section into its 1/16 (or 40 acre) parts. The intersections of these lines met at the desired corners of the 40-acre tract; they were positively identifiable by close inspection of the appropriate contour line, ridges, ravines and other features. Added to the strip topographic maps were the adopted numbers for all the corners. This made an exceedingly convenient and readily usable field guide and record. To it the aerial photographs were added and carried in the field.

The field staff was equipped with small field compasses,—each being mounted on a "Jacobs Staff"—and also with the customary tapes and other accessories. The staff consisted basically of Mr. King (project supervisor), Mr. Dodd (Forest Service recorder) and the author, together with George Bacon and Emmett Spencer (field aids and laborers, and truck-jeep drivers). Field operations were begun on November 13, 1957. By use of truck or car, aerial photos, and topographic map—or perhaps by walking—we arrived at a corner site. Diligent search was then made for marker or bearing trees. Only twice was it possible to find vestiges of the original Government Survey sufficient to make possible corner location or restoration. For the other corners positively identified, that identification was made possible only because the county surveyors in past years had visited and perpetuated the corner, added new bearing trees, and made official record of such data.

When properly authenticated corners were found, existing markers were replaced with standard reinforced concrete posts, bearing bronze caps. For full section corners, the posts were $6\times6\times36$ inches and for 1/16 corners $5\times5\times30$ inches. Caps for the section corners were bronze plates three inches in diameter and stamped by the manufacturer to read "Phelps County Survey Marker." In appropriate spaces the plate stamping was completed, so as to read (for example) "Corner to Secs. 1–2–11–12, T. 36 N., R. 9" Set 1957 by C. V. Mann." For every corner, not less than two—usually three or four—new bearing trees were tied to the corner by bearing and distance. The county surveyor has a special tree blaze used in Phelps County—this was used on this project—two sidewise blazes on the tree about 5 feet above ground and three deep notches below the blazes, so as to directly face the corner.

Where no sufficient corner evidence warranted present monument setting, as well as where corners were actually found, targets for spotting from the aerial flight were built. Usually the target was offset from the corner, in a nearby spot open to the sky or with the brush cleared enough to make it visible. The most effective target center was an automobile tire, painted white. Out from it were placed four white-painted boards $1''\times12''\times6$ ft., laid at right angles, thus forming a very conspicuous target cross. At times, the target centers were sheets of iron 3 feet square, with a bull's eye painted thereon. These sheets were usually raised five feet or so from the ground, and nailed to the tops of oak saplings cut off to that height. Light wire stays were passed from sheet corners to other saplings, for anchorage. The targets were secure against disturbance by roaming cattle. Where corners had been found and monumented, they were tied to these targets by bearing and distance (usually very close), using the small field compasses set to allow for local magnetic variation. Where corners were not presently found, they were later located by bearing and taped distance from targets and known position from targets.

Out of the 133 originally set government corners, as perpetuated by county surveyors, 56 were positively identified, authenticated and approved by the county surveyor. Thirty-two of the 125 desired 1/16 corners were finally so located, authenticated and approved. The bronze plates were stamped in the field, aside from the lettering the manufacturer had already placed.

Having by meticulous search and consideration of all available evidence so set monuments and targets for and at every positively identifiable corner, and having placed similar targets as close to the probable location of all the other missing corners, several days were spent in running special *third* order traverses within the township, in open and advantageous places where targets and corners could be tied to the traverse. This was done to provide an "on-the-ground" measuring stick with which to check aerial location of these same targets. In addition, several *secondary* triangulation stations, also tied to targets, were then tied, with precise triangulation, into several Coast and Geodetic Survey triangulation stations, both inside and outside the township area. These stations were also "targeted," so as to be covered when the aerial flights were made. This work was finished on Feb. 25, 1958.

With the foregoing work completed, the township area, plus area covering the outside Coast and Geodetic Survey stations, were "flown" on March 16, 1958, with a two-engine monoplane made by Beech Aircraft Co. The engines were of 450 H.P. each. The camera carried was a Zeiss RMK 21/18 Topar lens, shutter speeds 1/100 to 1/1,000 sec.

Flight *over control* was at altitude of 7,800 feet—and for strip runs 9,800 feet. The lens had an 8.25 inch focal-length.

The control flights extended sufficiently east into Township 36 North, Range 8 West, to take in U. S. Mo. Highway 63, as an aid in control. Flight northward took in the Coast Survey triangulation station at the Frisco bridge across Gasconade river. The "strip" flights were along center lines of each east-west tier of sections—first west over sections 1 to 6, then back over 7 to 12—and so on. The photographic films were processed in the Photogrammetric Unit of the Forest Service using a Zeiss C-8 Stereoplaneograph. Attached electronic equipment made up a typed record whereby each of the approximately 360 set field targets was definitely and accurately positioned and recorded with their "x" (east-west) and "y" (north-south) coordinates, *in FLEET* with reference to the Missouri (Mercator) Plane Coordinate Net—which is itself tied into the precise triangulation net of the USC &GS. The prime meridian for the south-central Missouri coordinate net is the meridian of 92°–30′ west longitude passing through the center of that part of the Missouri net.

These target coordinates were then sent to the Milwaukee office of the Forest Service, where a staff headed by Ray Fassett and Victor Hedman computed the *X* and *Y* coordinates for each of the recovered section corners. The same staff, conforming to accepted Federal and State requirements governing restoration of lost and destroyed corners, then established the "*X*" and "*Y*" coordinates for all the corners now missing. In doing this, they used accepted principles of "single" or "double" interpolation of corners, whichever was properly applicable.

With these computations completed, the field party was ready to monument each of the missing corners. From each respective target the corner was located by taped distance and bearing. This field work was completed May 18, 1959. The County Surveyor had been in the field, hunting and authenticating corners, supervising corner setting, and in the office digging up records—for 66 days. The other members of the field force spent at least twice that time in the local field.

The final work consisted in making the revised township plat, placing on it the bearings, distances and the corner numbers for the entire township. There followed typing the detailed record for each individual corner—how found and authenticated, how monumented and witnessed, and what else was done. Included were the "*X*" and "*Y*" Missouri Coordinate Net values for each corner. The plat measured 18×24 inches. The detail notes were first written up in terms of feet, tenths and hundredths. The original plats with detail notes, have been officially filed with the Phelps County Recorder and in the office of County Surveyor. This, I believe, makes me the first official in the United States to file such a photogrammetric plat.

The original fields notes, expressed in terms of feet, were changed to chains and link in the final detail notes—this change was made at the urgent request of the U. S. Bureau of Land Management and to the keen regret of those who executed the survey.

An Appraisal of the Effectiveness of Photogrammetric Method

The author has been through a complete restoration survey of a Federal land survey township. Also since 1903 he has been closely associated with the conventional transit-tape-stadia methods of surveying, including meridian establishment from solar and Polaris observations. He has practiced in the steep mountain areas of Colorado, Nevada and California, both in general practice and as a United States Mineral Surveyor. Because of this experience he feels fully qualified to assert that this photogrammetric method of restoring sectional corners is entirely superior to the old conventional transit-tape methods.

Photogrammetry offers a degree of unity over the entire surveyed area, hard to achieve otherwise. As computed for this project, and on the basis of comparing ten targets located (a) from ground work, by traverse; and (b) from aerial computation, the apparent errors for nine of the targets, ranged from 0.00 ft. to 1.6 ft., the arithmetic mean being 0.6 ft. The tenth target was off by 7 feet—this error or difference was run down and corrected.

In two separate areas in the steep mounains of Colorado the author was associated with corner location and identification made by transit-tape-triangulation methods. Based on this knowledge he regards the present project methods as being very far in advance in respect to completeness, unity, and detail over the older conventional methods. In one area, along Clear Creek Valley, at Georgetown, Colorado—a region of unusually steep mountain slopes—the several U. S. Mineral Surveyors operating there laid out a precise triangulation network extending up and down the valley for six or more miles, with a width of some four miles back on valley slopes. The triangulation stations were usually not over 1,500 feet apart. Following the triangulation, all known section corners were tied to the net, and the coordinates of each station determined and also the coordinates of the sectional corners, and many corners of old patented mining claims. Complete field and office notes were then made up and filed with each participating surveyor. That job could have been handled far easier through using photogrammetric methods.

As to relative costs, no final summation of costs for the Phelps County project has yet been made. For actual "Leg-Tiring Work" that was and is involved, the author would a thousand times prefer the project as handled than by the transit and tape method.

MODERATOR KENNEDY:

I know of nobody who is a more ardent supporter than Dr. Mann in the field of cadastral survey of the individual practitioners. He has described in detail a method that within the near future, I am sure, will be accepted practice throughout the State.

The next speaker according to the program is Professor Bryner. Because of illness he will not be with us. This is much regretted. Instead, Mr. Jerome Berry will read the prepared paper.

Professor Bryner is a Professor in the Department of Civil Engineering of the University of Utah. He is a member of the Rocky Mountain Region, American Society of Photogrammetry, and immediate Past Chairman of the Utah Section, American Congress on Surveying and Mapping. He is on the Board of Directors, Utah Chapter of the American Public Works Association. He was conference director and proceedings editor for the Annual Surveying and Mapping Conference held at the University of Utah, devoted to Land Surveying, Photogrammetry and related subjects.

*Photogrammetry Used in Land Transfer of an Area that Was Transferred from the United States Government to the State of Utah**

PROFESSOR C. C. BRYNER,
Dept. of Civil Engineering,
Univ. of Utah,
Salt Lake City

THE proposal for this panel is in three parts: recognition, cost and accuracies. Regarding recognition, the Bureau of Land Management in 1958 made a survey of ten townships in southeastern Utah. This project differed from other similar tests in that its purpose was to survey only the Township exterior and the four school sections that were to pass into State ownership. This project was in rough terrain and was not intended as a corner reclaiming project. Since the principal objective was to survey specific sections the planned work did not include effort in all parts of the Township. In this particular case, the remote control characteristic of the photogrammetric procedure made possible pinpointing any specific need or a location for a particular point or corner, without extensive traversing into the interior of the Township. This is a critical contribution to the general cadastral surveying problem.

This survey was made to facilitate transfer of title from Federal to State government. This certainly indicates recognition of the method as acceptable in the administration of the Federal lands.

A problem does exist, however, in the area of acceptance by local government agencies and title companies. One contribution to this

* The paper was read by Mr. Jerry Berry.

problem is frank and open analysis of the errors that have been found in the photogrammetric procedures. I personally object to the implication in the reports of some tests that the conventional steel tape procedures were used to locate the errors in the photogrammetric procedure, without specifically throwing out the unknown factors and errors that exist in the taped method. This statement is necessary because of those whose confidence in the older method, is based only on continued use of that method.

Item 2: The records are available for some cost experiences. A large spread and average of unit cost data have been obtained. Typical of this spread is $180 per mile for one project, and $240 for another.

The importance here is not that the costs vary or that the photogrammetry is expensive but rather that the detailed circumstances of field conditions and engineering procedures have been and will remain varied until some specific routine becomes accepted as a standard. Until this happens it will probably be difficult to obtain cost figures for comparison to standard procedures for which we have a wealth of historical record.

The individuals who read these test results with an eye to the factual data can evaluate each circumstance. The real problem is, that many a personal conclusion has been drawn from average figures only. This is all right in itself, but all too often this person lends no support to photogrammetry or refuses to support further use of a modern tool or method due to stubbornness or prejudice based on casual observations.

I personally believe that the question is not only: Can photogrammetry compete, but rather can we afford to properly design a method which will accomplish any desired result? History has proven only one thing, and, that is, that we have a method available that has been satisfying our needs in the past. There is no doubt about the validity of the equation accuracy equals money. But there are those who seem to doubt that the use of photogrammetry will accomplish accurate results. Doubtfulness as to the accuracy of the end product often stems from the application of a design test program that includes such things as available photography, existing data, and other trial items which result in the presence of many errors.

As to the question: Can a properly designed photogrammetric engineering procedure meet our specified accuracy requirements? There must be an unreserved "Yes." The design balance procedure just mentioned includes the necessary premise that each step in the procedure must meet every aspect of accuracy requirements for that particular step, and that no sacrifice is made in any step.

It is proven that first-order plotters, such as the Zeiss C-8 Stereoplanograph, can supply the foundation for a net of the photographic image to an accuracy of one and one-half feet with reference to the control network upon which the photogrammetric solution has been based. This can be accomplished when all of the preceding steps taken in the total project meet all the accuracy needs of that particular step.

The accuracy of each step must follow the general criterion that any following step cannot observe or detect the preceding error as greater than the smallest quantity that particular step can measure.

This suggests that such elementary factors as scale selection becomes critical. That on one to six thousand photography, the floating mark of the C-8 covers a circle approximately two-thirds of a foot in diameter. The employment of any graphical solution in any step must be such that at the scale of the particular work a human mechanical error must not bring about an error that can be measured, and thus accumulate through following steps, if it is to be certain that the final answer is to be near the accuracy of the ability of the final machine step.

With relatively flawless control of second order, at all points and a proper mathematical solution to the bridging problems with control on every fourth model, the adjustment problem will produce a random error of not more than one and a half feet.

Now if we are willing to program a sequence of steps to conform to this general criterion and if the final accuracy specification is in accordance with realistic needs, then the photogrammetric engineering procedure can serve in solving any such measuring problem.

MODERATOR KENNEDY:

The preceding papers have shown the application of photogrammetric methods to cadastral surveying. The next paper goes one step further. It shows the subsequent extension to digital computations.

The paper will be presented by Noel M. Benson. He is a partner and vice president in the firm of M. J. Harden Associates, in Kansas City, Missouri, Photogrammetric Engineers. He attended Kansas State University. For two and a half years he was Assistant County Engineer of Dickinson County, Kansas. He served in the U. S. Air Force for four years. Subsequently he was employed by Howard, Needles, Tammen & Bergendoff; in 1955, he was first assistant in charge of electronic computations for a 650 IBM computer, and later in obtaining contracts for the Photogrammetric Section. He is a member of the American Society of Photogrammetry and the American Society of Civil Engineers.

A Relationship of a State Coordinate System with Respect to Full Control Surveys with Subsequent Readout and the Use of a Digital Computer to Develop Geometric Layouts and Subdivisions

NOEL M. BENSON,
Vice Pres. M. J. Harden Assoc., Inc.,
Kansas City, Mo.

OUR company is primarily a participant in this panel because the opinions of a small organization are highly important in determining the relationship between photogrammetry and cadastral surveying. It was through the development of photogrammetry that our firm originally started growing. The increasing development in new instrumentation and in advanced techniques in the computer field have created the belief that it is necessary to undertake a closer relationship of these two specialized fields. Accordingly we have undertaken the development of a group of computer programs, that could be used in conjunction with a photogrammetric base map.

A new subdivision development of any size is taken as an example.

We must first realize the importance of the State coordinate grid system. Through using a coordinated group of points, or of any other points, we are able to undertake almost any type of geometrical manipulations and to obtain both a complete horizontal boundary survey and the final computations for any type of subdivision which could be laid out.

The first step in undertaking a new development is to obtain aerial photography at a low enough altitude to permit photogrammetric mapping by stero plotting equipment at a scale of 1″ equals 50′ and with a contour interval of one or two feet. Next, control planning for the entire flight of photographs is undertaken. We tie our horizontal control into a government coordinated control mark of at least second-order accuracy. From this point a second-order boundary traverse is run around the property limits of the tract of ground to be subdivided, picking up enough horizontal points to accurately scale the model or models in the plotting equipment.

After the horizontal boundary survey has been completed and all of the property corners and the horizontal points have been calculated and adjusted for the error of closure within second-order accuracy, the photogrammetric base map is plotted with stereo plotting equipment. The job is then given to either the consulting engineer or to the developer who is actually determining the subdivided arrangement of lots. With the base map he will try to determine the most feasible subdivision layout that can be produced, taking into account the topographic features of the land and also, the zoning regulations. After completion of his scale drawing, he is ready for undertaking the job of computing all of the lots.

To facilitate computation of his information we have developed an electronic computer program. Although the basic operations in such a calculation are simple—for example, computation of the intersection point of two lines or a line and a curve—the key to efficient computation is the organization of many individual calculations into an orderly array whereby each individual problem is interrelated to problems previously solved as well as for use in answering anticipated questions.

It was our intention to develop an *internal-referencing* program capable of solving any geometric figure inherent in subdivision design—in only *one* pass through the computer. Now, after two and one-half years of development, the program is operative, fully tested and is available for general application.

Specifically, our program will: 1) calculate bearings and distances of all sides of the boundary traverse, check the error or closure against the specified quality of the surveyed traverse, and distribute errors to balance the traverse; 2) compute bearings and distances of all lines in the street centerline traverses; establish points of curvature, tangent intersection, tangency and curve center and compute curve lengths, radii and deflection angles, or degree of curvature; 3) compute bearings and lengths of all lot lines; 4) compute lot areas in acres and square feet; 5) compute coordinates of all boundary traverse points, street centerline points and corners.

All computations are in sufficient detail and accuracy to permit field stake-out directly from the computer output, and to permit description for plat and abstract preparation. The engineer need furnish only: 1) a dimensioned, preliminary layout of the subdivision; 2) field information on the boundary survey; 3) any special criteria pertinent to design.

As a result of the first two projects recently completed, it is our belief that our programs will result in important economies while developing more complete accurate information.

Another area of development in our organization, which has somewhat of the same type of problems previously mentioned in respect to our subdivision work, is in the field of pipeline engineering.

The major photogrammetric difference between a pipeline project and a normal subdivision project is primarily due to the length of the pipeline. This in most cases will be many miles in length. For this reason we have been using a computer program for bridging a large group of stereo models between government bench marks in a triangulation system. The first job that was undertaken was in very adverse terrain because it was very heavily wooded and with miles of swamp land.

We planned the horizontal and vertical ground control from the horizontal and vertical bench marks over to the pipeline with at least two bands of control in each flight line. By using a first-order stereo plotter the project was then bridged between the terminal models at each end of the flight strip.

The selected horizontal and vertical points —the output from the plotter—were then taken and by using a computer adjustment program, the points were adjusted to a suitable tolerance of error for the pipeline company. Each individual adjusted model was set into Kelsh plotting equipment; all of the apparent property lines, construction obstacles, and pipeline profiles were extracted. The coordinate location of all pipeine P.I. points and property corners were then extracted, and the rights-of-way descriptions for each parcel of ground crossed by the pipeline were computed. All of the pipeline alignment, property descriptions, and the areas of each parcel of ground were obtained by again using the series of computer programs that were used in the subdivision computations.

A rectified photo mosaic was made of the entire pipeline project. This was divided into plan and profile sheets, each of which contained all of the property data and engineering data necessary for staking the pipeline in the field. With the exception of obtaining our bands of ground control, all of this was done without putting any survey parties on the property owners ground prior to obtaining purchase of rights-of-way.

Also by using stereo plotting equipment we were able to prepare in the office all of the crossing permits for highways and railroads. In this particular project we also made numerous alignment changes without putting a surveying party in the field.

The pipeline company staked our line in the field in order to check our method of obtaining alignment. The company had very high praise for our accuracy. With this procedure it also was able to win condemnation proceedings against four property owners.

By using the described procedures, we are able to eliminate a large amount of man-hour cost and expense.

We believe that there is a very close union of photogrammetry in the field of cadastral surveying. To date we have only a small amount of this work but we hope to undertake a lot more, and also to develop more procedures to reduce the cost and to increase accuracy tolerances.

MODERATOR KENNEDY:

The next speaker is Professor Eldridge. He is an Associate Professor, in the surveying areas of instruction, in the Department of Civil Engineering, University of Illinois at Urbana. Previous employers include the Aero Service Corporation and the U.S.G.S. His 24 years of active surveying include property surveying, topographic mapping, construction surveying and surveying teaching. He received a B.S.C.E. degree from the University of Tennessee, and a M.S. in Civil Engineering from the University of Illinois. He is a member of the American Society of Civil Engineers, American Congress on Surveying and Mapping, American Society of Photogrammetry, American Society for Engineering Education, and Canadian Institute of Surveying. He is Secretary of the Illinois Registered Land Surveyors Association. He was ACSM representative to Commission 1-A at the Tenth Congress of the Federation Internationale des Geometres, in Vienna, in 1962. Prof. Eldridge was co-author with Mr. Curtis M. Brown of the book "Evidence and Procedures for Boundary Location," published by John Wiley & Sons in 1962. I understand there is planned a later edition or another book on that same subject. Also compiled is the "Bibliography of Property Surveying Literature."

Legal Aspects of Photogrammetry Used in Property Surveys

PROFESSOR WINFIELD H. ELDRIDGE,
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Univ. of Illinois,
Urbana, Ill.

THE principal responsibility of the property surveyor is that of locating on the ground the physical limits of property ownership from evidence, or that of describing such property from a physical location. This activity depends upon metrical data of length, direction, and position. Many devices, from rods and chains, through invar metal tapes to electro-magnetic emissions have been used to measure these quantities.

Why not use photogrammetry?

As property locations vitally depend upon the physical evidence of measurements, the surveyor is often faced with the problem of qualifying his measurements so that they can be admissable in the courts of law. Therefore, it might be appropriate to consider three aspects of legality to decide how photogrammetry may serve in this capacity. First the question of evidence, next, the quasi-legal specifications and contractual agreements, and lastly, professional registration.

MEASUREMENT EVIDENCE

In many of the court decisions, the judge has ruled that a measurement is merely an estimate. This estimate, with sufficient proof, may be admitted as proper evidence. An Illinois judge has stated:

> "Objection to a question intended to measure a witness' capacity to estimate distance by stating the length of the court room should have been overruled"—Heidler Hardwood v Wilson & Bennet, 243 Ill app 89)

In a North Carolina case:

> "Where in an action of trespass, a surveyor has testified that he knows the boundaries of the land in dispute as described in the complaint, he may testify that they are within the natural boundaries set out in a grant from the State. . . . being of substantial fact."—(Berry v Cedar Works, 184 N C 187).

And in Alabama:

> "In a boundary dispute, an expert surveyor, who had the description of the line before him and had surveyed and located it, was properly permitted to testify as to where the true line ran." —(Burleson v Gillam, 205 Ala 673).

These expert opinions must be based on the best available evidence. In a Wisconsin case, the court has ruled:

> "In surveying a tract of land according to a former plat or survey, the surveyor's only function or right is to relocate, upon the best available evidence, the corners and lines at the same place originally located. Any departure from such purpose and effort is unprofessional, and, so far as any effect is claimed for it, is unlawful." —(Pereless v Gross, 126 Wis 122).

Can the surveyor testify to measurements when he has not performed the act on the ground?

The courts have favored *actual* meaurements, made on the *ground*. For example:

> "Actual measurements might be more convincing"—(Reynolds v Stimson, 121 Kan 431).

> "Lines actually run and marked on the ground are the best evidence of the true location of a survey."—(Matson v Poncin, 152 Iowa 569.)

> "Facts held to show that surveys were made on the ground, and that surveyor acclaimed position of unmarked lines and corners called for with certainty from identified positions."—(Anderson v Schaefer, 205 SW 300.)

I can find no cases in the reports involving the *admission of photogrammetric evidence*, but there are many cases referring to photographs. In a Federal Court case:

> "It is not necessary that a witness would take the photography himself, or see it made, in order to testify to its correctness."—(Missouri Ry of Texas v Magee, 49 SW 928.)

The Illinois Statutes, Ch. 51, Sec. 3, state that photographs may be admitted as original evidence if properly qualified. But there is a little more concern when quantitative data are taken from photographs. For example:

> "In determining value of a farm taken for airport, *exclusion* of photographs of property on ground that they did not give accurate description of terrain with slopes, elevation, and valleys, was not abuse of discretion."—(Lutz v Allegheny County, 327 Pa 589.)

And:

> "Where the photograph is offered, not as a mere general representation of the locus in quo, but to show distances, relative sizes, or locations of objects, it may be very deceptive and misleading."—(Ligon v Allen, 162 SW 536.)

I present these references to cases to illustrate that in a lawsuit, especially the first to involve photogrammetric measurements, it will take considerable proof to qualify the complied data, particularly if they are to overcome "actual" ground measurements. *Metrical photography has not been a science long enough in this country for the courts to take judicial notice, and the surveyor who depends on these data to prove property location, may need to educate the judge and jury on the entire process from initial control to final adjustment.*

REGULATIONS AND SPECIFICATIONS

Can photogrammetric measurements be used for property surveys that are controlled by one of the many sets of requirements and specifications? The New York, the Pennsylvania, and the Florida Title Association each have "Minimum Standards" for title insurance policy surveys. One paragraph is identical in each of these three:

> "The surveyor's field work must be performed with transit and steel tape and its accuracy proved by a closed traverse."

The Pennsylvania Title Association "Minimum Standards" has added:

> "In rugged terrain it is recommended that vertical angles be measured on excessive slopes. All measurements made with steel tape should be corrected to a temperature of 68 degrees Fahrenheit."

Apparently there is no place for a camera and plotter here.

The *Technical Standards for Property Surveys* approved by ACSM in 1946 was a little more foresighted with the statement:

> "Measurements shall be made with instruments capable of attaining the required accuracy for the particular problem involved."

The more recent *Minimum Standard Detail Requirements for Land Title Surveys*, approved by both ACSN and ALTA earlier this year is even more flexible with the statement:

> "The surveyor's field work must be performed to locate the property corners accurately."

The question might arise however: What is *field* work?

Many specifications such as those of the Interstate Highway Act, are based upon the government specifications for Triangulation and Traverse. These orders of precision are based upon geometrical conditions that can be satisfied with traverse or triangulation but cannot be readily adapted to photogrammetric compilation.

In Massachusetts, the Torrens System of title registration is more in force than in any other state. The Land Court is rather specific in requiring that all surveys be made with an engineer's transit fitted with a vernier, reading to one minute or a smaller division, and a steel tape with graduations to feet, tenths, and hundredths of a foot. Surveys must be recent actual surveys, made upon the ground with a closed traverse, and preferably around the periphery of the property.

The Land Court has this to say regarding photogrammetry:

> "Nearly all surveys and plans for the Land Court are most economically made by using the standard survey procedures. However, the Court recognizes that in relatively few instances, other methods of surveying and preparing plans are highly satisfactory. Generally these other methods, such as triangulation and photogrammetry, must be done in conjunction with the usual methods and must be limited to particular portions of the area covered by the survey or plan. In such instances, consultation with the Engineer for the Court before performing the field work is recommended, since additional information about the work will be required for the Land Court records. Such information might consist of a statement of the type of instrument or other equipment used, a copy of the actual field notes and calculations, and a statement on the precautions taken to assure that the final plan is a true report of the facts existing on the ground."[1]

QUESTIONS OF REGISTRATION

Nearly all of our States require registration, either as land surveyor or a professional engineer, before a person can perform property location services. In most of these registration acts, there is no hint of photogrammetry. In Illinois, Chapter 133, land surveying is meant to include:

> "Surveying and measuring the area of any portion of the earth's surface, the lengths and directions of the boundary lines, and the contour of the surface for their correct determination and description, and for conveyancing or for recording or for establishing or reestablishing, locating, defining and making or monumenting land boundaries or lines and the platting of lands and subdivisions thereof;"

And in Missouri, Ch. 344:

> "'Land Surveying' means the surveying and measuring of the area of any portion of the earth's surface; locating and measuring the lengths and directions of the boundaries of land, and the contour of the surface thereof; and the plotting of lands, and subdivision thereof in this state, for compensation in any form or manner."

May a registered land surveyor make his measurements photogrammetrically in either of these states? Can a non-registered photogrammetric engineer make measurements of real property boundaries without violating these statutes?

The picture is somewhat clearer in California where the Statute (Ch. 41, Sec. 8726) states:

> "A person practices land surveying within the meaning of this chapter who, either in a public or private capacity, does or offers to do any one or more of the following:
>
> (including)
> d. Determines the configuration or contour of the earth's surface or the position of fixed objects thereon or related thereto, by means of measuring lines and angles, and applying the principles of trigonometry or photogrammetry."

If land surveyors are to employ photogrammetry, or if photogrammetrists are to make measurements for property location, there will arise several questions of registration. Must the land surveyor be fully qualified to make the high-order measurements employing the ultimate of photogrammetric cameras and plotters? If photogrammetry comes under the state registration acts, who of the team should be registered, the pilot? the photographer? the plotter operator? the compiler?

The state registration examination in California has included some questions on photogrammetry. How can such examinations be administered to test the qualification of a photogrammetrist for the serious and responsible job of property location?

[1] From *1959 Manual of Instructions for the Survey of Lands and Preparation of Plans.* XXII, (1), p. 27, Massachusetts Land Court, Boston, 1959.

MODERATOR KENNEDY:

There are many points Professor Eldridge has raised that are new to the audience. We will probably require more explanation during the Question and Answer Period.

Our last speaker, Mr. Daniel McVay has been engaged in photogrammetric, geodetic surveying, and cadastral surveying work since 1935, when he started with the U. S. Forest Service Division of Engineering in Missoula, Montana, constructing maps from aerial photographs. Except for five years with the U.S.D.A. Agricultural Adjustment Administration Photogrammetric Laboratory in Salt Lake City, Utah, and World War II Army service with the 29th Engineer Topographic Battalion in the Pacific, all of his employment has been with the U. S. Forest Service. Assignments have included surveying and mapping projects in six states, and the Philippine Islands. In 1958, he was assigned to and was in charge of setting up a Property Line Location program in the Forest Service Northern Region until his transfer to Washington, in 1961. He is a member of the American Society of Photogrammetry, the American Congress on Surveying and Mapping. He is a Registered Land Surveyor in Montana, and presently is a Civil Engineer in the Alexandria Unit of the Surveys and Map Branch, Division of Engineering, U. S. Forest Service, Washington, D. C.

The Use by the Forest Service of Photogrammetry in Cadastral Surveying to Help Solve Existing Land Problems and to Prevent Further Problems from Developing

DANIEL McVAY,
U. S. Forest Service,
Alexandria, Va.

During the last few years, various papers on cadastral surveying by photogrammetric methods have been presented at meetings such as this. Also interesting and informative articles have appeared in various publications.

Common sense indicates that legal acceptance of a cadastral survey should be based on its compliance with required standards of accuracy and adequacy, instead of the tools used to do the work.

Aerial photographs (and instruments for their use) should be as much a working tool of the modern cadastral surveyor as the transit, chain, subtense bar, theodolite, electronic measuring device, desk calculator, or automatic data processing.

It is no longer a question of whether or not satisfactory cadastral work can be done by photogrammetric methods but, rather, a question of which working tool, or combination of tools, is best suited to the particular job to be done, the capabilities of personnel assigned to the work, and the facilities available for their use.

It must be remembered that in using aerial photos to obtain angles and distance measurements—sufficiently accurate for cadastral survey purposes—the very best photography, aerial cameras, comparators, ground control, and work techniques are required.

Photogrammetry can be highly effective in other phases of cadastral work, such as corner search and recovery, reconnaissance, planning, etc. Moreover, required work processes are simple; necessary equipment is inexpensive; and photography adequate for this purpose is often already available. Forest Service need for, and use of, these processes may be of interest.

The U. S. Forest Service is responsible for the administration and management of 186 million acres of Federally owned land. Much of this land is intermingled with land owned by others in complex ownership patterns requiring about 820,000 property corners to control over 208 thousand miles of ownership boundaries between this land and the land of nearly $\frac{3}{4}$ of a million adjoining landowners. About 5% of this land is within the metes-and bounds survey areas, the remaining 95% being in the rectangular survey system.

The relative merits (or lack) of these two systems of land surveying, are well-known and need no elaboration. However, one or two comments may be in order; the first is that these two systems have at least one thing in common—no effective steps have ever been taken to preserve the surveyed lines and corner monuments. Consequently, their physical evidence has been and is disappearing at an alarming rate; secondly, in the rectangular survey system, the common (but shortsighted) practice is to grant title to rural parcels of land by legal subdivision-of-selection description, without requiring a survey to subdivide the section and to mark the lines and corner points on the ground. This practice has created countless miles of ownership boundaries that have never been surveyed. Furthermore, many of the corners required to control these subdivision surveys have now disappeared. Hence, many rural landowners have clear title and excellent records showing exactly what they own, *on paper*, but nothing to show their property lines and corner-point locations *on the ground.*

As land and natural resource values rise, management activities become more intensive and boundary problems more acute. To meet these problems, the Forest Service has set up a Land Line Location Program. Activities of this program fall logically into three main parts:

(1) To recover what remains of the boundary controlling corners and to preserve their locations with enduring markers.
(2) To plan and to execute the surveys required to reestablish the lines and corners that are lost, and to establish such new lines and corners as are needed.
(3) To mark these property boundaries so that their location is readily apparent on the ground, and to set up a continuing maintenance program to insure that these lines and corners will not be obliterated.

Considering the magnitude of the job, funds available for this work have been limited in amount. The need to recover the remaining property corners before all evidence completely disappears is urgent. Therefore, the most activity is being directed toward corner recovery and official remonumentation. Also, regardless of whether subsequent cadastral surveying is to be done by photogrammetry, ground methods, or some system not yet invented, controlling corners of previous official surveys must first be recovered. The use of aerial photos in corner search enables the searcher to find corners that he otherwise wouldn't find, and to do it in less time. To accomplish this the approximate corner locations are spotted on the photos. Then, they are used in selecting the best route to the corner, and in making a search in the immediate vicinity of the point, shown on the photo, as the approximate corner location.

To spot these corner locations on the photos for this purpose, we "work backward" through the stereoplotter, and project the section corner location shown on a good base map to its corresponding position on the photo.

With practice this action can also be taken without a stereoplotter. By matching photo features with the corresponding features on a reliable large-scale map, and using the survey notes and plats and any evidence of land lines that appear on the photos, the approximate corner locations can be satisfactorily positioned on the photos.

In addition to the photos, the field men are furnished copies of the notes, and plats of all previous official surveys in the project area, a record of the land status and ownership, suitable maps and all available information on the known condition of the corners to be recovered.

A 2-inch-to-the-mile (or larger) scale planimetric map is used to show the land status, ownership, and boundary lines. By using suitable symbols, it also serves as a progress record to show corners found, corners searched for and not found, condition of boundary lines, etc. Furnished with these items, plus a few simple tools and suitable transportation, the search party operates with a minimum of lost motion. At each recovered corner, bearing tree signs are placed on remaining authentic bearing trees. A precise photo identification of the corner is obtained. Paint, flag cloth, etc., are used to mark the corner so it can be found again. Also, the search party makes a complete written record of conditions found at each corner point visited. After the corner search we know which corners are lost, which need remonumenting to prevent their being lost, and which, if any, are still in good condition.

The next step is to remonument the corners that need it. To be of any value, an enduring corner monument must be set and the work must be done by, or under, the direction of those who have the authority to do the work and to prepare an official record of work done. The Bureau of Land Management has such power to survey land that has at any time been patented. Either the BLM or the State authorized surveyor is authorized to survey boundary lines between these two categories of land.

The remonumentation party, therefore, includes either a Bureau of Land Management surveyor, or a land surveyor, authorized by State law, depending on the status of the land involved. When the surveyor is a Bureau of Land Management employee, that Bureau supplies its official corner monument. Also, the remonumentation notes become a part of its official survey records.

When the services of a registered land surveyor are used, the surveyor's name and registration number are stamped on the cap, along with the corner designation letters and numbers, at the time the corner monument is set. Due to the present lack of State law governing the official preparation and filing of survey records for work of this type done in rural areas, the Forest Service in several States provides the forms for recording the work; it retains this record until arrangements can be made for its official recording and filing.

After the corner search and remonumentation has been completed in an area, it is known what additional surveys are required and what information is needed for sound work planning. Arrangements can then be made to have the work done under the proper authority and by the survey method best suited to existing conditions. If photogrammetric methods are selected, the procedure outlined below is used:

(1) The photos, and photo identifications of remaining corners (recovered by the procedures described above) are used to construct an accurate large-scale planimetric map showing previously surveyed land lines and, by protraction, the new lines that are required.

(2) The locations of missing corners, and new corners to be established, are projected to the photos. The photos are then used to locate these approximate positions on the ground.

(3) All existing usable horizontal and vertical control is recovered, and any required additional control is established. These positions are converted to State Plane Coordinates.

(4) Ground targets are placed on all points to be used for horizontal and vertical control and on all recovered property corners. Also, placed on the approximate locations of property corners that have been lost and new corners that are to be established.

(5) After the ground targets are in place, the area is photographed with a precise mapping camera.

(6) These photos are used in a first-order stereoplotter to bridge between horizontal control to obtain machine coordinate values for each property corner target set (Item 4). Bridge adjustment and State Plan Coordinate values are then obtained by electronic data processing.

(7) With the coordinate values obtained for the targets on the known corner points and the original survey notes, the coordinate positions are computed for the corners that are lost, then for the positions of the new subdivision of section corners that are to be established.

(8) With the coordinate positions of the lost corner points, the new corner points that are to be established, and the ground targets set near them in the field, the distance and direction is computed from the target to its respective corner point location.

(9) The distance and direction from the target to the corner point is laid off on the ground and suitable corner monuments and accessories are set.

(10) Official notes and plats are prepared.

Photogrammetry has attained an important place in cadastral surveying just as it has in mapping, road location and design, and many other engineering functions.

The use of photogrammetry includes reconnaissance, survey planning, guidance in ground search for survey evidence, obtaining survey measurements and preparing official survey plats and notes. One or more of these photogrammetric processes can be effectively used on most cadastral survey jobs.

Tests[1] conducted in the United States and in other countries have established the fact that measurements adequate for cadastral work can be obtained by photogrammetric methods.

[1] King, J. E. "Photogrammetry in Cadastral Surveying," PHOTOGRAMMETRIC ENGINEERING, June 1957.

King, J. E. "Advantages of Photogrammetry in Cadastral Surveying," Surveying and Mapping, March, 1962.

Van Zandt, F. K., "A Photogrammetric Cadastral Survey in Utah," PHOTOGRAMMETRIC ENGINEERING, September, 1959.

The development of more stable-base aerial films, more precise aerial cameras, electronic instruments for rapid and accurate ground distance measurements, and comparators capable of measuring photo-point coordinates to an accuracy of a few microns are increasing the survey potential of photogrammetry.

I should add that any failure in the use of photogrammetry for the processes described by me, could I think, be attributed primarily to the weakness of the system that is used. I am not qualified to speak on the legal aspects; however, I believe that a survey that is certified by a Registered Land Surveyor or an official who is operating in that capacity should be judged to be legal. It may not be any good as are a lot of ground surveys. Nevertheless I believe it is legal and it stands as such until somebody proves that it isn't any good.

Now as far as getting confusion between the photogrammetrist and the land surveyor, I can see no conflict or reason for any. If the land surveyor wants to use photogrammetric methods, he can either become a photogrammetrist himself or he can go to someone who is and get the services that he wants. A photogrammetrist can't certify to a survey unless he is registered as a land surveyor or an engineer. So there should be no conflict of interest; I think such conflict is needless.

MODERATOR KENNEDY:

I thank you, Mr. McVay, for your excellent presentation of the uses of photogrammetry in cadastral surveys by your organization.

At the QUESTION AND ANSWER PERIOD which follows, there is only one ground rule: Those having a question should direct it to the panel member concerned. Use this microphone and give identification as to name and the organization represented. This will help the other members of this group to understand both the question and the background of the questioner.

MR. BROWN of San Diego: Mr. Anderson, you gave some figures on the experiment that you ran. As I recall them, when the corners were 50 feet apart, you had about a 0.13 error, and when the corners were 1,800 feet apart, you had an error of about 0.23.

The change in distance is 52 feet up to 1,800 feet. That is about a thirty-six times larger distance and the error is changed from approximately 0.13 up to approximately 60% more.

What is the linear relationship between distance between points on photography as to the error, or is there any relationship between the points, or is the error dependent upon just the constant, no matter how far apart the points are?

MR. ANDERSON: I will run through those figures again. There were ten distances of from zero to fifty feet. The standard deviation there was thirteen-hundredths of a foot. For the distances from fifty to 100 feet it was fifteen-hundredths of a foot; from 100 to 150 feet, fifteen-hundredths of a foot; from 150 feet to 500 feet, it was eighteen-hundredths of a foot; and from 500 to 1,200 feet it was thirteen-hundredths of a foot.

The standard error in the distances which were compared—eighteen to fifty feet—give a much more realistic indication of the accuracy, because you can measure distances from zero to fifty feet very accurately on the ground. The comparison would be less reliable for the longer lines because errors in distances measured on the ground will increase with the increase in length of line. If we disregard the deformations in the stereo model caused by film shrinkage—lens distortion, of course, was taken into account here—the photogrammetric measurement should be fairly consistent, regardless of length of line. If I have a model where I can measure lines that are 200 feet long, the standard deviation should be the same for the group of long lines as for a group of short lines.

MR. BROWN (San Diego, California): The point is that surveyors must change their mode of thinking when they go to photogrammetry. There is no such thing as an error in proportion to distance, in proportion to two points. You get the same error whether it is five foot apart or a hundred foot apart.

MR. ANDERSON: That is about right for the photogrammetric method.

MR. MAYER: I am in private practice. I would like to question Dr. Mann on the quality of corners. I understand that some searched for were internal corners rather than on the periphery. Were those corners originally set when the Government surveyed the area? What is the basis for searching for a corner at that location?

DR. MANN: Our County Engineers or County Surveyors through the years have established those corners according to State law. That is, by statute.

MODERATOR KENNEDY: How about the panel members. Possibly Mr. McVay would like to ask a question.

MR. McVAY: I ask Mr. Benson to tell us what system he used to get the photogrammetric corner location back onto the ground to identify the property lines on the ground itself?

MR. BENSON: When we undertook this bridging on the pipe line project, the rights-of-way were actually described by apparent property lines. As I mentioned, this particular line was in a very rough terrain, the wooded area was very heavy and there was a lot of swamp area involved. What few property lines were available were held to be accurate and were used as the base of other property parcels. Only a few corners were available even though we hunted on the ground with our horizontal survey party, and with the use of a Registered Land Surveyor. We tried to find all the property corners that were available and marked these. However, we had to go by apparent properties from there on.

MODERATOR KENNEDY: There is time for one more question.

MR. SIME: At the last Board Meeting of the American Society of Photogrammetry we established a new Committee on the subject of this Panel—the Application of Photogrammetry to Cadastral Surveying. I make this announcement so that anyone that would like to work on this committee may make arrangements for this by contacting the Committee Chairman. I want to make it very clear and to say Amen to what Mr. McVay said, that there certainly isn't any conflict of interest. We believe that photogrammetry can be a tool to cadastral surveying, and that the purpose of this Committee is to improve the opportunity for service.

MR. JAMES P. WEBB (Army Map Service): This comment may not apply directly to the land survey measurement. However, there is a film now developed and being used that as far as we can tell has the same stability as glass. In fact, we are considering using this film on the stereoplanigraph and A-8 and to sandwich it onto an optical flat rather than using a glass plate.

Second, so far as distances are concerned, I can't speak regarding very short distances. We have found through many tests and experiments, that there are systematic errors that creep in when you triangulate many models in a series. However, there are also accidental errors in a single model. The systematic errors we cannot accurately balance unless we know exactly what is causing them and usually we don't, but we find that the adjustment of the random error in a strip of five models give results with about the same average that you would get in a single model.

MODERATOR KENNEDY: With Mr. Webb's remark we will close this panel, and again express appreciation to the panel members and to the audience for their attendance and participation.

ATTENTION MEMBERS

The *Nominating Committee* will meet in *October to nominate candidates* for President, First Vice-President, Second Vice-President and five members of the Board of Direction. Members who wish to suggest Members for consideration as candidates for these offices are welcome to do so. The committee will give serious *consideration to such suggestions provided received by the Committee Chairman before October 15.* Address suggestions to Charles W. Culkin, 403 Orleans Circle, Vienna, Virginia.