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Special Report 82

Photogrammetry and Aerial Surveys

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Special Report 82

Photogrammetry and Aerial Surveys

Current Highway Applications
and
Technical Excerpts from
Committee Meeting Discussions

HIGHWAY RESEARCH BOARD
of the
Division of Engineering and Industrial Research
National Academy of Sciences—
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Foreword

Since its establishment in August 1956, the HRB Committee on Photogrammetry and Aerial Surveys has been actively engaged in encouraging and aiding highway departments and organizations in the adoption and use of photogrammetry and aerial surveys wherever applicable in highway engineering. The aims of the committee are:

1. To perform and encourage research for development of new and improvement of old methods and procedures of using photogrammetry and aerial surveys;
2. To point the way to adaptation of photogrammetric, aerial, and related methods and procedures from other fields of engineering to highway engineering;
3. To act as an evaluation and correlation center, and to disseminate information and data obtained by the committee and by others;
4. To work for standardization in nomenclature and terminology; and
5. To encourage and participate in the preparation of reports and papers on utilization and accomplishments.

In 1962, the committee prepared and distributed to the 50 States and the 10 Federal units employing aerial surveys for highway purposes a questionnaire pertaining to seven phases of aerial surveys used in the successive stages of highway engineering. Forty-seven States and the ten Federal units responded, and a summary of the responses was published in Highway Research News No. 6.

Operational reports were also solicited informally by committee members from several States, some of the Federal units, and consultants accomplishing aerial surveys. The 18 reports received are published in Part I of this Special Report. These reports contain historical information, organizational and functional arrangements, and specific practices in one or more of the phases of aerial surveys—including procurement of aerial photography, use of photographic interpretation, accomplishment of essential ground control surveys, employment of plane coordinates, and utilization of photogrammetry. Inasmuch as the reports were initially prepared in 1962, recent practice (if changes occurred since then) are not included.

By detailed review of these reports, an insight may be obtained into the various practices and unique solutions to highway engineering surveying problems by aerial surveys. Whether the aerial photographs, measurements, and maps, as needed for engineering and other highway work, are obtained by negotiated contract or by an aerial survey unit of the staffing organization, the principal benefits, in the form of more detailed data than would otherwise be available, accruing from aerial surveys are the same. All other States are invited to submit reports regarding their practices and research activities in aerial surveys.

Part II of this Special Report comprises excerpts from the minutes of committee meetings held in 1962, 1963 and January 1964. Included is significant information pertaining to specific practices and research in several States from which written reports have not been received, as well as excerpts of reports made informally at committee meetings by members and other interested individuals. Together, Parts I and II provide a representative insight into details of aerial surveying practices in the highway engineering field in the United States and point to progress expected and some particular phases in which research should be undertaken.

From each user of these excerpts, questions, contributions to committee activities, or suggestions for improvement of the services performed by the committee are requested. Remember, progress can best be achieved and benefits therefrom extended to everyone, when there are forthright exchanges of experiences—including both failures and successes—in the development and use of aerial surveys.

William T. Pryor, Secretary
Photogrammetry and Aerial
Surveys Committee

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Part I

Current Highway Applications of Photogrammetry and Aerial Surveys

STANDARD SIZE PLAN SHEETS PREPARED FROM CONTROLLED AERIAL PHOTOGRAPHS IN GEORGIA

L. W. Verner
State Highway Locating Engineer

The varied topography in Georgia, from mountains approaching 5,000 ft in elevation to coastal areas where major towns are at an elevation of only 20 to 30 ft above sea level, presents a variety of problems and challenges to both highway and photogrammetric engineers.

In the summer of 1960, the Division of Surveys and Aerial Mapping received a request from the Urban Design Department for a base map covering a section of I-95 in McIntosh County, Ga. The specific area involved was an area 15 mi long lying parallel to the coast and just west of the town of Darien. Some of the problems involved were: (a) unavailability of accurate base maps at any scale; (b) no suitable aerial photographs, (c) smooth and nearly level topography with a maximum elevation of 35 ft above mean sea level; and (d) stipulation that the work be done immediately (during the middle of the summer when normally the foliage would be most dense). The time of year, however, was not catastrophic because the area involved is completely covered with 20-yr-old pines, coastal grasses, and other perennial vegetation.

A topographic map could not be compiled feasibly with a Kelsh double projection, stereoscopic plotter because of the levelness of the ground (some areas average only a 2-ft elevation differential per horizontal mile) and presence of the perennial vegetation. Moreover, topographic maps would have little value, because some map sheets would not contain a single contour and would be nearly void of planimetric features. It was, therefore, decided to produce the best planimetric map or substitute possible in the least time and at the least expense.

The project area was photographed using a 6-in. focal length, Wild RC-8, aerial camera from a flight height of 1,500 ft. After processing, the contact prints were sent to the field where a horizontal distance was measured between identifiable points on every fifth photograph. From these measurements, an enlargement factor was computed for each photograph. The photographs were enlarged approximately 3 diam to a scale of 83⅓ ft to 1 in. (1:1,000). These photographic enlargements were assembled on boards to form a semicontrolled photographic mosaic covering the plan area of a standard plan-and-profile sheet.

The photographic mosaics were then copied and reduced to the desired scale of 100 ft to 1 in. Points on the highway centerline had been hubbed and targeted before photography for ease of identification on the photographs. In copying the photographic mosaic, the image of the highway centerline was used to center the photograph in the plan area, and centerline measurements were used to further refine scale. The copy was produced on DuPont Cronar Masking Film to give a continuous-tone or low-contrast negative. A standard plan-and-profile sheet was copied to produce a negative mask, and the plan area was cut out. The negative of each segment of the photographic mosaic was inserted in the plan area of the mask and the complete plan-and-profile negative assembly was inverted to make it reverse reading. This negative was contact printed, using a pinpoint light source, on DuPont Commercial Matte Film producing a positive film of a plan-and-profile sheet with a photographic base in the plan area. Caution was used to produce a low-contrast positive film, because most blue-line paper is of high contrast. The negative was inverted to produce the desired positive. It is possible to draft on the clear upper surface of this positive without damaging the photographic images printed to represent the bottom surface.

This program, while not entirely new, proved to be highly successful under the conditions described. Field personnel using these sheets for highway location, right-of-way, and/or construction purposes were definitely pleased. Part of the acceptance was attributed to the fact that scale was easy to control because there were little or no image displacements due to absence of ground relief and lens distortions. The photographic base showed all identifiable images.

Considerably less time and expense were required to produce this type of photographic base map than would have been incurred in compiling a topographic or planimetric map. General acceptance of photographic base maps wherever topography is fairly flat is expected throughout the State Highway Department of Georgia, as other divisions learn of their advantages and the possibilities.

TOPOGRAPHIC MAPPING OF PATHS BETWEEN MICROWAVE TOWERS

W. S. Higginson
Photogrammetric Consultant

The problems and work of compiling topographic maps for use by Western Union in placing towers for its system of microwave transmission is very similar to those of reconnaissance survey mapping to determine feasible routes for highways, especially where distances of 30 mi or more are involved. Topographic maps were compiled for microwave paths, beginning in Los Angeles, Calif., extending northwest to Oakland, and thence eastward to Sacramento, Salt Lake City, St. Louis, Cincinnati, and New York City; and for branch microwave paths to Denver, Houston, and Kansas City, and from St. Louis to Chicago, Detroit, Cleveland, Niagara Falls, Syracuse, and Boston.

Before the aerial photography flights were made, the tower sites were located by the microwave engineers. Aerial photographs were then taken of the path strip between these points at a scale of 1:24,000. The average distance between tower stations was about 35 mi, and ranged between 25 and 40 mi. The position of these tower points was determined in the field by tying to known points in the existing network of horizontal control. With the coordinates known (usually geographic coordinates), the midpoint coordinates and the distance between the microwave stations were computed. The geographic coordinates were conveted to the State plane coordinate system.

To control these strips adequately for compilation of the topographic maps with a Kelsh stereoscopic plotter, an attempt was made to control each stereoscopic model independently. After several attempts, it was decided the needed horizontal control could be obtained for each stereoscopic model more easily and economically by a radial line plot. The compilation manuscript, convenient in size for a Kelsh instrument workin surface, is large enough to cover a strip 2.5 mi long in flight-line direction. For a microwave path map of 30 mi, a radial plot bridge of 20 stereoscopic models is required. Adequate control for this length of bridge with close tolerance would be almost prohibitive in cost if measured by the standard transit traverse and spirit leveling methods in the field. After considering the allowable tolerances in horizontal position and elevation, it was decided to use existing information wherever available and to resort to field survey methods only in isolated areas where maps or other control information did not exist.

For these 30-mi microwave path maps, copies of current or late compilation manuscripts of 1:24,000-scale topographic maps with a 10-ft contour interval were found to be suitable. These manuscript copies have numerous points identifiable on aerial photographs, thus providing adequate control for the individual stereoscopic models. The exact scale for the models within the strip was determined by accurately joining together existing topographic maps of the area through which each microwave path extended and connecting the tower sites with a straight line. This line was checked by comparing with the coordinates of the two tower sites and their midpoint previously computed. A segment of this line, beginning at the midpoint and extending 2½ mi in either direction, became the baseline for single model compilation manuscripts, which, of course, are at a scale 5 times larger than that of the aerial photographs and of the assembly of 1:24,000-scale topographic maps. X and Y distances to map points were measured from this baseline and plotted on the compilation manuscript. Using these points, the radial line plot was adjusted to achieve correct scale between the two tower sites.

This system of establishing horizontal control for each stereoscopic model allows all control points required in the map compilation, both horizontal and vertical, to be established for the microwave corridor or path through utilization of an adequate distribution of the well-defined and identifiable image points, as transferred from the original maps of the region. Because some corridors extended across geographic quadrangles where no modern 1:24,000-scale topographic maps exist, needed control data were ascertained from smaller or larger scale maps where possible.

The northeastern part of the United States is well covered with modern 1:24,000-scale topographic maps, which can be obtained from the map information office of the U.S. Geological Survey. This office can also supply river survey maps and Army Map Service 1:250,000-scale series of maps covering most of the United States. These published maps are reduced-size copies of the compilation manuscripts. The larger scale manuscripts, when enlarged photographically, are useful in providing map coverage of the quadrangle areas not covered by the 1:24,000-scale topographic maps recently compiled by photogrammetric methods. Thus, the careful and judicious use of available map information and ground control provided the control data needed in making the radial plot bridge for reasonable distances and to sufficient accuracy.

Maps compiled by photogrammetric methods generally produced satisfactory corridor mapping. Only where the old ground-survey compiled maps were used for control were the corridor maps less accurate than required, as determined by the profile measured from the maps between microwave transmission towers. The 1890 series of topographic maps were unusable.

Tower height increments were 25 ft. Corridor width for profile control of microwave transmission was 0.5 mi. Clearances below a straight line between towers over ridges, trees, and man-made features on the ground had to be sufficient to prevent any reflection. The tower sites were selected by reconnaissance on the ground before the mapping was undertaken for obtaining profiles along each corridor 0.5 mi wide. Tower site selection was more difficult over the less rugged regions, as between Omaha and Houston, than between cities in mountainous areas. Mirrors were used to test lines of sight during tower site selection.

The dependability of the microwave corridor maps was questioned by the contracting agency, Edwards and Kelsey, microwave engineers. Following the few field checks which were thought to be advisable, the necessary control was established and substandard areas were remapped. Evaluation of the project, by use of data obtained during the investigations, gave the contracting agency and the mapping contractor, International Mapping Co., Los Angeles, confidence in the profiles measured from the maps.

For highway reconnaissance survey purposes, this system of establishing control for and compiling small-scale topographic maps can be used very well with the incurrence of minimum costs. Highway agencies having a minimum of photogrammetric equipment can produce topographic maps of this type with no outside help, except for the aerial photography. By such mapping several feasible routes between designated terminal points may be economically compared.

USE OF AERIAL SURVEYS IN REGION 8, U. S. BUREAU OF PUBLIC ROADS

George B. Forrest
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By January 1962, there were approximately 320 lineal mi of topographic maps on different routes within this region. These maps vary in scale from 100 ft to 1 in., with a contour interval of 5 ft, to 400 ft to 1 in., with a contour interval of 20 ft, depending on the character of the topography surveyed.

Because of dense timber and brush cover over many sections of highway location, aerial photographs are being used to study route alternatives before sending field survey crews into the areas. The photographs are used in stereoscopic pairs and in assemblies as uncontrolled photographic mosaics to determine each route alternative, as governed by land usage, drainage areas, soil interpretation, and location and classification of surfacing material sites. The possible route alternatives are drawn on the aerial photographs in stereoscopic correspondence with the ground and used as a guide by the chief locator assigned to the survey for field review. By image identification, the locators can find and evaluate each route alternative meeting horizontal and vertical alignment standards.

Aerial vertical photographs are used to compare feasible route alternatives and to prepare a preliminary reconnaissance design for cost analysis of the route alternatives throughout any given area. On some routes, alignment and grade have been developed and grading qualities have been obtained directly from the photographs by the parallax measurement method and electronic computer offset daylight program. On one route the initial reconnaissance cost analysis indicated that the ground survey was in the wrong area. As a result of this survey and comparison, a new route was selected at substantial savings in cost and time. A highway on the new route will be opened to travel in approximately 4 yr, whereas a highway on the original route would have required 10 to 15 yr for completion with normal appropriations. Since the initial reconnaissance survey and route comparisons, a preliminary survey by aerial methods over the unfinished portion of the route and the design and construction plans have been completed, and the centerline has been staked in the field. The designed and staked location followed very closely the route location and initial design comparisons for cost estimating.

Approximately 3,000 mi of alternative route possibilities have been reviewed within this Region by direct use of aerial photographs. Vertical, horizontal, and subsidence movements along centerline on one route in Montana have been checked by re-establishing control for aerial surveys on right-of-way monuments placed before the earthquake near West Yellowstone.

Recently essential surveys were made and 123 mi of road realignment were designed for the U. S. Army Corps of Engineers within the Libby Dam area in Montana. The reconnaissance survey and route location were made by use of photogrammetrically compiled topographic maps at a scale of 1,000 ft to 1 in. with a 20-ft contour interval. These maps were enlarged 1 diam to a scale of 500 ft to 1 in. The objectives of this reconnaissance survey were to relocate existing Forest Highway and Forest Development and access roads which will be inundated, to determine the side of the reservoir for which each routing is best adapted by topography, type of materials, and design criteria, and to outline in detail the areas where additional aerial surveys should be made.

The basic control was established and targeted by the Corps of Engineers along a railroad in the bottom of a canyon at intervals of approximately 1,000 ft with vertical control points on each side of the canyon at 6-mi intervals. The routes were then photographed and mapped at scales of 200 ft to 1 in., with a 5-ft contour interval, and 400 ft to 1 in., with a 10-ft contour interval, in specified area. Mapping was accomplished with a first-order optical train photogrammetric instrument, bridging control along the route between the targeted control points. The topographic maps were enlarged to 1 diam to obtain scales of 100 ft to 1 in. or 200 ft to 1 in., as desired. The preliminary location design and construction plans were made using these enlarged topographic maps, supplemented by stereoscopic examination of the aerial photographs used to compile the maps.

Approximately two horizontal control stations per mile have been established along the proposed realignment on each side of the reservoir at points intervisible along the railroad tracks. These stations are for positioning control in staking the designed centerline along each route. They will also be used by the Corps of Engineers as reference points in right-of-way surveys and as basic control for surveys of the reservoir area. Angles and distances were measured by T-2 theodolite and Electrotape instruments to third-order accuracy.

Topography in the area of survey is rugged with sections of heavy timber and brush cover. Therefore, after the preliminary design was completed, a P-line was staked on the ground as close as possible to the designed projection of the highway centerline, using established control stations as the origin of horizontal position. The object of this traverse is to check the topographic maps. In areas where the contours check, no additional topographic measurements were made other than for structure site surveys. In areas where a discrepancy occurred between the contours and the field surveyed P-line, ground survey methods were used under the timber and through brush areas to measure cross-sections. In areas adapted to aerial surveys, the P-line was targeted to serve for basic control and another set of aerial photographs was taken at a larger scale to measure photogrammetrically cross-sections across the proposed alignment directly from the photograph.

After all essential adjustment of alignment and grade were made in the field, the corrections were noted on the plans and the centerline was staked on the ground by computed offset from the P-line. This alignment was reviewed by participating agencies. Once agreement was attained, the designed alignment was staked for highway construction.

The aerial photographs obtained are useful for outlining proposed recreational areas, noting connecting roads to timbered areas, measuring drainage areas to determine size of structures, and ascertaining preliminary classification of materials.

Vertical photography is on file for 60 percent of the routes on which construction or route location surveys are under way. The scale of this photography ranges from 600 ft to 1 in. to 1 mi to 1 in. The contact prints of such aerial photography are used extensively by locators in making route reconnaissance surveys and soil investigations.

Contract Procedure

Aerial survey work is contracted to responsible photogrammetric engineering firms in its entirety as a proposal for engineering services. Award is not necessarily on the basis of the lowest proposal, because experience, time required to complete the work, availability of equipment and type of equipment must be considered.

Each survey area is reviewed by existing aerial photography and small-scale topographic maps compiled and published on a quadrangle basis, or by field inspection to determine scale of photography for route reconnaissance surveys and for preliminary survey mapping of selected routes by the aerial survey contractor. The scale varies from 1,000 to 2,000 ft to 1 in., for reconnaissance survey mapping photography and from 200 to 600 ft to 1 in. for preliminary survey mapping photography, depending on the type of topography within the limits of the proposed route survey area. The width of coverage on the reconnaissance photography will vary from 5 to 15 mi, depending on route possibilities and drainage areas within the area of survey.

Before the contractor places ground survey control targets, the reconnaissance survey photography is furnished on which are outlined in detail the mapping boundaries and the approximate location of the proposed survey route. A control line is flagged on the ground along or near the center of the route. The contractor establishes station markers in the ground to serve as control survey points along the flagged line at about 10 points to the mile and places a target on each point before photographing the mapping zone. Distances and angles are measured by electronic measuring devices and T-2 theodolites. Approximately five vertical control points, or pass points, are located on each stereoscopic model.

Permanent station markers are established as concrete monuments at intervals of ½ mi. Test traverses are measured along the control line by field survey parties.

Topographic maps at a scale of 100 ft to 1 in., with contours at a 4- to 10-ft interval, depending on topography, are compiled by the contractor on map manuscripts 24 in. wide and 72 in. long. The accuracy of the photogrammetrically compiled topographic maps are tested by traverses and profiles measured by field survey parties.

The designed alignment is projected on the topographic maps, and the mathematical description thereof is actually computed by plane coordinates. Topographic data and listings of grading quantities are obtained by automatic data processing. In general, the "Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958" is used in the administration of all contracts awarded for aerial photography, ground control surveying, and topographic mapping by photogrammetric methods.

USE OF AERIAL PHOTOGRAPHY IN REGION 15, U. S. BUREAU OF PUBLIC ROADS

(Eastern National Forests and Parks)

An aerial photography contractor was engaged in March 1961 for topographic mapping of a 10-mi section of the Natchez Trace Parkway in Mississippi. The preliminary P-line was staked on the ground by conventional survey methods.

To stake the right-of-way, it was first necessary to design a centerline of the highway for the projection of the right-of-way taking lines and preparation of the development plans.

The Public Roads division office set photographic targets on survey control points. The targets were cross-shaped and made of white and black cloth strips 8 in. wide and 10 ft long. All vertical and horizontal survey controls were tied to the targets, which were centered by a tack in a wooden stake driven flush with ground surface.

Under the negotiated contract, the aerial surveys contractor furnished the following:

1. A route map at a scale of 500 ft to 1 in., and two sets of contact prints, 9 by 9 in., of the 500 ft to 1 in.-scale vertical photography.
2. State plane coordinate computations for all preliminary P-line control points and for all other control points for which photographic targets were set.
3. Topographic maps extending 1,000 ft on each side of the P-line at the horizontal scale of 100 ft to 1 in. with a contour interval of 5 ft and three sets of prints of each map sheet.
4. An index map of the map sheets and a photographic index of the aerial vertical photographs.

For such work, the contractor was paid $500.00 per linear mile of highway.

The contract stipulated the contours should not be in error by more than ¼-contour interval (1.25 ft) for 90 percent of the points tested, and not more than ½-contour interval for the remaining 10 percent. Numerous checks made by the U. S. Bureau of Public Roads showed that in no case was a contour in error as much as 1.25 ft; for over 90 percent of the points tested the contour error was less than 0.5 ft. Horizontal accuracy was also very satisfactory.

The 2,000 ft width of topography mapped provided much latitude in design for centerline projection. Such width also contributed greatly to the expeditious design of drainage structures and preparation of a complete set of construction plans.

Photography flying was done on March 14, 1961, before the trees began leafing out. The airplane used was a Cessna 180; the aerial camera was a K-17 type (modified) with a 6-in. focal length Metrogon lens tested by the National Bureau of Standards. The contractor completed all photography, plane coordinate computations of control, and photogrammetric compilation of the topographic maps by the latter part of April 1961.

The cost of such topographic mapping, if done by conventional ground survey methods would have been approximately $16,000 and would have taken from 4 to 5 mo to complete

The cost of this contract was $4,909.21 and less than 2 mo were required to complete topographic mapping of a route band approximately 2.5 times as wide as would have been surveyed if the work had been done by a survey crew on the ground.

Successes achieved in aerial mapping on this project encourage serious consideration of the use of aerial surveys for measuring original ground cross-sections of the constructed highway for computation of earthwork in payment of construction contractors. If this experiment proves successful, aerial survey methods may be used for measuring cross-sections of future grading projects along the Natchez Trace Parkway.

A test survey is under way to compare costs and accuracy of ground survey and photogrammetric methods for measuring earthwork pay quantities on a 4-mi mountain grading project on the Foothills Parkway in eastern Tennessee. The original ground cross-sections were measured by conventional ground survey methods and by use of precision stereoscopic plotters. After grading is completed, the constructed highway cross-sections will be measured by both methods.

The initial aerial photography for these tests was taken after the construction contractor had completed clearing operations and before any grading was done on the project. The photography was taken by the Tennessee Valley Authority and the photogrammetric measurement of cross-sections of the cleared construction zone was done by the Aerial Surveys Branch, U. S. Bureau of Public Roads. The ground control surveys were made and field measurements of cross-sections of the same zone were accomplished by field division personnel of Region 15. After completion, all cross-section data will be sent to the Bureau's computer center for computation of earthwork volumes.

In the Washington, D. C. metropolitan area, most highway survey areas have been photographed, and small-scale topographic maps compiled from photograpy by photogrammetric methods are available from other Government agencies. These maps, along with contact prints of available stereoscopic coverage by aerial photography, are utilized by Region 15 in reconnaissance surveys for route determination and comparison purposes. Once the best route has been determined, large-scale photographs are taken and used in compiling topographic maps for design purposes at scales of 100 or 50 ft to 1 in., according to need, with a contour interval of 5 ft and 2 ft, respectively. It is expected that an aerial survey contract will be let for any future highway survey and design project where topographic maps of adequate scale are not available and where the area of survey is extensive enough to justify such contracting.

Region 15 also uses contact prints of aerial photography in conjunction with the available topographic maps to determine the size of drainage areas for the design of drainage structures.

USE OF AERIAL SURVEYS IN CONNECTICUT

David S. Johnson
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Wethersfield, Connecticut

Aerial photography for highway engineering purposes was first used by the Connecticut State Highway Department in 1930 for locating, developing schematics, and preparing preliminary right-of-way acquisition maps for the Merritt Parkway through Fairfield County, a distance of approximately 38 mi. The photographs were enlarged to the scale of 200 ft to 1 in., the scale to which planimetric maps were prepared from the photography.

Using photography taken in 1934, aerial photographic mosaics were assembled of the entire State at the scale of 600 ft to 1 in. and were used for many years thereafter for planning purposes.

In 1944, the first topographic maps compiled by photogrammetric methods were used by the Highway Department. This mapping was done at the scale of 200 ft to 1 in., with a contour interval of 5 ft, and covered a route band of topography 1 mi wide and 12.9 mi long between the cities of Hartford and New Britain. Since then, the Connecticut State Highway Department has considered photogrammetry as one of its most valuable tools and has used it constantly. The Highway Department has obtained over 800 lineal mi of topographic mapping as follows:

Length (mi)	Scale (ft to 1 in.)	Contour Interval (ft)	Width of Mapping (mi)
780	200	5	1
70	100	2	0.5
20	40	1	0.2
6	40	Location survey	-

Maps compiled photogrammetrically at the scales of 200 ft and 100 ft to 1 in. are used primarily for highway route planning (route determinations, comparison, and selection), and at the scale of 40 ft to 1 in. for the preliminary location survey and design.

As the Department has no established photogrammetric section, its aerial photography and photogrammetric work are accomplished under negotiated contract by established photogrammetric firms. The maps are reviewed before acceptance by the State, and to assure compliance with specifications, they are field checked for accuracy of location of cultural features. Also, test profiles are measured along test traverses to check the accuracy of contours.

Projects are scheduled so that the aerial photography may be taken during November and December or in the early spring. Because of the variability of the weather, the average number of days with 10 percent or less of cloud cover is only 5 or 6 a month during these periods. Also, during these same months, there are high winds and local updrafts that seriously affect flying for photography of all scales, but particularly for photography taken from low flight heights for topographic mapping at the scale of 40 ft to 1 in.

Preliminary survey planning and the early determination and comparison of alternative highway locations are done by use of the standard topographic maps published at the scale of 2,000 ft to 1 in. as quadrangle sheets by the U. S. Geological Survey. The State of Connecticut is participating on a continuing basis with the U. S. Geological Survey in the cost of preparing these maps. When the general route zone of the highway location has been determined, topographic maps of the route are compiled at the scale of 200 ft to 1 in. from currently taken aerial photographs by precision photogrammetric methods.

The various location alternatives first developed on the small-scale topographic maps are transferred to the topographic maps compiled at the scale of 200 ft to 1 in. The larger scale maps reveal the undesirability or impracticability of part or all of various centerline locations, and the possibility or the necessity of adjusting and refining others. It is usually possible to add new location alternatives for study to replace those discarded. These alternatives can then be developed to fully engineered and scaled schematic plans for the highway. Centerlines may be shifted until the most acceptable profile is apparent, the limits of the separated roadway and divided highway sections are determined, conformity with alignment and gradient criteria are checked, interchanges are engineered to scale, and the treatment of intersected roads are shown. Comparable cost estimates of the various location alternatives are made with the aid of the photogrammetrically compiled topographic maps. After deciding which of the highway location alternatives is best, its design is further refined to provide as complete a guide as possible for its location surveying on the ground and for preparation of construction plans at the scale of 40 ft to 1 in. The location and plane coordinates of instrument points on the proposed survey baseline are determined, based on the Connecticut State plane coordinate system.

Due to the accelerated highway program in Connecticut, it has been necessary to employ consulting engineers for survey and for design. Many of these are using photogrammetry in varying degrees for topographic map compilation at the scale of 40 ft to 1 in. as follows

1. For interchange areas it is usually more desirable to determine exact ramp locations during the latter stages of design. It is becoming increasingly more common to photograph these areas and photogrammetrically compile topographic maps with contours on a 1-ft interval, thus enabling the designer to measure cross-sections from the maps for any desired location.
2. In urban areas the base map is prepared by photogrammetric methods, supplemented by ground surveys. The cross-sections and/or spot elevations are later measured by ground surveys.
3. The use of aerial photographs, enlarged to the topographic mapping scale of 40 ft to 1 in., is increasing, particularly in cities. These enlargements are used in studying proposed highway locations on developed properties, as a means to refine the proposed baseline and as an aid in property appraisal and acquisition.
4. There have been several instances where the consulting engineers, in order to complete preliminary design, approximate grading quantities, and establish grade lines, have had topographic maps compiled photogrammetrically of highway routes with a 2-ft contour interval. The cross-sections and profiles measured from these maps are later revised in accordance with data obtained by ground surveys.

The Highway Department contemplates greater use of topographic maps compiled at the scale of 40 ft to 1 in. in the future for highway location, design, and preparation of construction plans.

USES OF PHOTOGRAMMETRY BY THE WISCONSIN STATE HIGHWAY COMMISSION

Since early in the 1950's the State Highway Commission of Wisconsin has contracted the services of a number of photogrammetric engineering firms to furnish topographic maps and allied data for the planning, location, and design of highways. By 1961, approximately 2,000 sq mi of aerial photography flying and 600 sq mi of topographic mapping were completed on highway locations within the State.

The small staff within the Design Section of the Commission is engaged principally in the administration of photogrammetric engineering contracts, construction of aerial photographic mosaics, and the training of engineers in appropriate phases of aerial surveys, including photogrammetry and photographic interpretation for highway engineering purposes.

Contract Administration

The services of photogrammetric engineering firms for taking aerial photography and compiling topographic maps have been engaged by negotiation rather than by bid, and excellent results have been attained. Specifications generally follow those prepared by the Photogrammetry for Highways Committee, jointly sponsored by the American Society of Photogrammetry and the American Congress on Surveying and Mapping, as published by the U. S. Bureau of Public Roads, with some variations brought about by local conditions of climate, topography, and land use.

Both fall and spring have been satisfactory for taking aerial photography for compilation of reconnaissance-type topographic maps to a scale of 200 ft to 1 in. with a 5-

ft contour interval. Spring has been consistently better than fall for the small contour interval and large-scale requirements of topographic mapping for the design of highway locations and preparation of detailed construction plans, because more detailed topographic conditions are discernible when grass and other vegetation has lain dormant under snow cover for several months during the winter. In addition, for States of mid-continent and high latitude location, such as Wisconsin, suitable photography may be obtained throughout a longer period of time during the spring. In fact, in the upper reaches of this State, fall flying is possible only for less than one week, and if weather conditions are adverse, it is not possible at all.

Because of the nature of the topography within certain highway project locations, many aerial survey contracts had to be tailored to provide contour interval and map scales that are both usable and feasible for route location and design. Although the topography of Wisconsin can be generally described as moderate, many areas exist where local relief precludes standard renditions of the flying height-contour interval relationship. Along the high bluff area of the Mississippi River in western Wisconsin and in the northeast and north central areas of the State, specifications were adjusted to allow for variable flight heights and contour intervals. Along the Mississippi River, for example, photography was flown at a flight height of about 3,000 ft above mean elevation of the ground. Two-foot contours were compiled over the existing roadway areas and in other areas where the slope did not exceed a 10-ft rise in 50 ft. Where the slope was steeper than a rise of 10 ft in 50 ft, only contours at a 10-ft interval were shown; however, supplemental contours were indicated for a narrow band adjacent to the roadway at a 5-ft interval. This contour variety facilitated design in an area in which it would otherwise have been difficult, if not impossible, to represent and measure configurations of the ground by use of one contour interval only.

Mosaic Construction

The Design Section has constructed a sizable number of individual photographic mosaics in various forms for reports and public hearings. Normally, 12-in. focal length aerial photography at scales of 800 or 1,000 ft to 1 in. is taken in conjunction with 6-in. focal length photography which is taken for mapping purposes. These are the most desirable photography scales for photographic mosaic compilation and use. In addition, use is made of 6-in. focal length photography from the U. S. Geological Survey and 8¼-in. focal length photography from the U. S. Department of Agriculture. The former is preferred, especially in areas of deciduous tree cover. Enlargements of aerial photographic mosaics have been very effective for presentation of route proposals at public hearings and preparation of preliminary engineering reports. Such mosaics, initially prepared for route reconnaissance and allied purposes only, have found their way into a number of other phases of highway engineering, such as planning and demonstrating highway construction progress.

Special Purpose Photography

Gratifying results have been obtained from the use of oblique photography for right-of-way purposes. Property owners are able to visualize the effects of a particular highway location on their property if the road centerline is superimposed in perspective on an aerial oblique photograph. About 75 flight line miles of oblique photography coverage were obtained recently by negotiated contract on the Interstate System. The consultant used a 12-in. focal length K-17 aerial camera, flew at a height of approximately 2,000 ft above ground, and took the photographs with a 30^{0} depression angle. Two sets of contact scale prints were furnished. The original film negatives were later used by the section's photographic laboratory for making additional contact scale prints and scale ratio enlargements as needed.

Effective use has been made of a cooperative arrangement between the Highway and Aeronautics Commissions. Aircraft and pilot are utilized on an hourly rental basis, and a photographer, equipped with a press-type camera from the public relations staff, is able to procure oblique photography coverage of specific locations on very short notice. A complete oblique photography record of 50 mi of Interstate highway construction, from location survey staking to roadway surfacing, was accomplished in cooperation with the U. S. Bureau of Public Roads using this arrangement.

Cross-Sections Measured Photogrammetrically

In 1958, aerial photography was taken over a section of highway approximately 12 mi long for experimentally measuring cross-sections by photogrammetric methods. District survey crews under the guidance of the consultant established all horizontal and vertical control necessary for the project. Cross-sections at every 100-ft station and at breaks in grade and ground slope were measured for about a 350-ft width across centerline and digital information was furnished in punch card form for subsequent input to an electronic data plotter. More work of this nature is planned.

Past experience using consultants for aerial surveys and mapping has led to present plans to continue negotiating engineering contracts for this type of service.

AERIAL SURVEYS AND USES OF PHOTOGRAMMETRY FOR HIGHWAYS

Aerial Surveys Branch, U. S. Bureau of Public Roads
Washington, D. C.

The Aerial Surveys Branch was officially established in 1952. This was not the beginning, however, of the actual use of aerial surveys by the U. S. Bureau of Public Roads. Instead, it was the culmination of more than two decades of use by a few employees of the Bureau of aerial photography for highway engineering purposes. The uses began elementally and were gradually increased in detail, precision, and scope. Creation of the Branch followed directly the successful completion of a comprehensive aerial survey to locate feasible highway routes through a 90,000 sq mi area in the central United States. Previously aerial surveys had been utilized advantageously on numerous projects for route location and design purposes. Among the significant project examples are:

1. George Washington Memorial Parkway, 1928,
2. Pioneer Road for the Alaska Highway in Canada and Alaska, 1942;
3. Inter-American Highway, 1947-48; and
4. Mississippi River Parkway (now Great River Road), 1950-52.

The principal responsibilities of the Branch are to:

1. Promote better design through use of aerial surveys;
2. Develop, improve, and disseminate information on methods, standards and practices;
3. Exercise leadership in writing specifications for aerial surveys;
4. Perform liaison and consultation services;
5. Conduct conferences and schools in aerial surveying for highway engineering purposes; and
6. Serve as a central source of information.

Aerial surveys for highways comprise taking and using aerial photographs, regardless of their type or scale and manner of use, while accomplishing the essential photographic interpretation (including photogrammetry and electronic computer applications) and requisite ground control surveys.

Reconnaissance Surveys

Reconnaissance surveys for determining feasible routes and comparing them to select the best route have been completed and reports have been prepared for highway projects of diversified traffic requirements and various construction standards in regions of Africa, Hawaii, continental and United States. In addition, route locations for numerous high-standard sections of the Interstate Highway System have been determined. All reconnaissance surveys are made by small-scale existing photography obtained from many different sources, supplemented by use of small-scale topographic and/or planimetric maps when available except around or through metropolitan areas where recent photography is required. Parallax measurements are made to locate the routes on gradients not exceeding the maximum established by the class of highway to be located. Photographic interpretation is employed in sufficient detail and scope to ascertain the qualitative controls of highway route location resulting from land use, topography, soil and ground conditions, and drainage. The feasible routes are delineated on the aerial photographs so that each segment is in steroscopic correspondence with the topography when the photographs are examined stereoscopically.

Reconnaissance survey reports are written according to the specific requirements of each survey. Some reports contain only brief narrative comments pertaining to route position and length and to general topographic conditions and the significant land uses, which combined with topography have controlling influence on the feasible route alternatives. Other reports include detailed route descriptions, soil conditions and analyses, sources of construction materials, estimated construction quantities for all principal items of highway construction, right-of-way and severance damages, alignment standards attainable, anticipated maintenance costs, and historic, archaeologic, and scenic or recreational areas served.

By way of illustration, the reconnaissance survey for the large route-location project previously mentioned involved the elemental measurement of parallax and computation of grades and horizontal curvature without benefit of ground control for photogrammetric use and photographic interpretation by stereoscopic examination of about 30,000 aerial photographs covering the entire 90,000-sq mi area. The final report included delineation on maps and evaluation of each feasible route and estimates of probable costs of right-of-way and construction for each 2,000-mi route of the 10,000 mi of route alternatives across 246 counties in ten States. The total survey cost was $140,000, averaging $14.00 per route mile, based on the total length of all alternatives. Such economic advantages alone justify utilizing aerial survey methods in the reconnaissance survey stages. An added bonus is better located and engineered highways, providing safety and service far exceeding that usually attained whenever the reconnaissance surveys are made on the ground only.

Preliminary Surveys

Preliminary survey mapping is usually done at the large scales of 100 ft and 50 or 40 ft to 1 in. on a joint research and project survey basis. The contour interval, usually ranging from 5 to 2 ft, is selected according to topography ruggedness and design requirements. All mapping is on datum of the State plane coordinate system adjusted so differences between map distances, as determined from the plane coordinates, and distances measured horizontally on the ground will be less than 1:5,000 or 1:10,000, according to the accuracy required in the basic control and in the mapping.

Survey projects initiated by regional offices of the U. S. Bureau of Public Roads are thoroughly examined through use of available small-scale aerial vertical photographs and topographic maps to determine the conventional procedure most expedient and economical for adequately accomplishing the required mapping. The procedure thus determined is then analyzed for adaptation or development of a new approach so as to produce either better accuracy, a more quickly accomplished survey, savings in survey costs, or a combination of the three. Materials and photogrammetric instumentation techniques are also analyzed and varied in order to reduce incidential expenses and improve procedures.

In preliminary survey mapping, new photography is designed and taken for each survey project. The photography is compatible with the inherent characteristics of the stereophotogrammetric instruments used for map compilation. Considerable planning is done to keep within the instrumental relief-height to flight-height ratios and to avoid photography scales exceeding practical working limits in map compilation with the available, double projection, photogrammetric instruments.

Work of the Aerial Surveys Branch seldom continues beyond the mapping phases of the preliminary survey stage of highway engineering into the detail design phases. Usually its activities are confined to specialized fields of using and advising in use of photogrammetry and aerial surveys for accomplishing essential work in highway engineering. The design work is done in other offices, adequately staffed to perform these duties.

Special Services and Research

Special services are a continual and important function of the Branch. Requests originate from many different sources, such as other Federal agencies, State governments, colleges and universities, regional offices of the Bureau, governments of other countries, and commercial firms. Some requests are merely questions pertaining to scales and types of aerial photography desirable for certain purposes. Other requests are for extensive review and analyses of aerial photography to determine soil conditions along a highway route and to locate sites for borrow of suitable construction materials.

The Branch has fulfilled three requests for specialists to go out of the country on short assignments: one to Ethiopia, one to Costa Rica, and one to Peru. In Ethiopia the work was to determine locations for possible highway routes; in Costa Rica the assignment was to review highway route location work performed by Costa Rican engineers and to make recommendations regarding the relative merits of the various route alternatives, in Peru, the assignment was to train Peruvian engineers in the principles and use of aerial surveys for highway engineering purposes. In addition, using aerial photographs furnished by the requesting agency, numerous miles of highway route alternatives have been located, delineated on the photographs stereoscopically, and compared; the most feasible route has been recommended throughout many States and other countries.

In response to requests, numerous trips have been made to regional and division offices of the Bureau to perform a consultant engineering service, especially in obtaining aerial survey services by contract for highway engineering survey and design purposes.

Since 1947, aerial survey training has been given to highway engineers, administrative personnel, junior engineers, and materials engineers of the United States and other countries. According to individual needs, length of training varies from 3 hr to 3 mo or more and includes basic principles and procedures, instrumentation and instrument operation, photographic interpretation, and basic and supplemental control surveys, as well as their applications in each stage of highway engineering. In response to specific requests, there has been an average of more than two aerial survey schools conducted each year for the past 12 years for engineers from all regions of the Bureau, from nearly every State, and from other countries.

Numerous articles have been written for publication by the Highway Research Board, the American Society of Photogrammetry, American Congress on Surveying and Mapping, American Society of Civil Engineers, the International Society for Photogrammetry, the U. S. Bureau of Public Roads, and the Pan American Highway Congress.

To achieve positive identification of ground control survey markers, special studies have been made to evaluate material, dimensions, and spacing for photographic targets.

As survey project work is done, research is accomplished to determine accuracies of bridging horizontal control by use of radial stereotemplets prepared and assembled from aerial photographs of different scales.

To determine the differences in measurement of earthwork pay quantities by both aerial and ground survey methods, cross-sections are being measured on one highway project in a rough mountainous area where clearing of the route was necessary before photography. The original ground cross-sections and the constructed highway cross-sections, measured separately by ground survey and aerial photogrammetric methods, will be used to compute the earthwork volumes and to compare them on a difference basis according to each method of measurement.

Data on survey costs relative to all types of highway surveys are compiled and revised on a continuing basis to keep cost records current and available to answer requests for information.

PHOTOGRAMMETRY AS APPLIED BY FEDERAL HIGHWAY PROJECTS OFFICE, REGION 9, U. S. BUREAU OF PUBLIC ROADS

The Federal Highway Projects office in Region 9, located in Denver, Colo., is responsible for the location, design, and construction of Federal Domain Highways in Colorado, New Mexico, South Dakota, North Dakota, Texas, Utah, and Wyoming. In administering Forest Highway funds, the region's responsibility is similar to that of a State highway department. Using highway funds administered by other organizations, such as the National Park Service, Bureau of Indian Affairs, and others, the Federal Highway Projects office serves as the road building agency.

The large area encompassed by the seven States, with their varied types of topography, weather conditions, and vegetational coverage, offers a real challenge to the progressive highway engineer in highway location, design, materials investigations, and construction. The wide latitude in climatic conditions presents an almost year-round opportunity to implement photogrammetry, electronics, and other advanced techniques. The remoteness of many of the highway projects within these States and manpower limitations makes the use of photogrammetry and electronics almost mandatory.

The Aerial Surveys Branch of the U. S. Bureau of Public Roads began training limited numbers of the Region 9 Federal Highway Projects personnel in aerial surveys and photogrammetry in 1950. Emphasis was placed on the effectiveness of aerial surveys and photogrammetry in reconnaissance surveys and in preliminary survey and design.

Between 1957 and 1959 personnel were trained in operating precision stereoscopic instruments, equipment was obtained, and preliminary surveys were made for highway location purposes by aerial survey instead of ground survey methods. Currently the full-time employees are one photogrammetric engineer, one Kelsh instrument operator, and four field survey parties, each consisting of a party chief and five to eight members. In addition, part-time engineering technicians prepare manuscripts for compiling maps, compute plane coordinates, and file photographs.

Aerial vertical photographs, in scales from 1:12,000 to 1:30,000, are used for each reconnaissance survey to assist in determining and comparing the feasible route alternatives, in selecting the best route corridor for large-scale topographic mapping, and in measuring drainage areas. These photographs are usually available from other Government agencies at reasonable unit prices.

The photography for large-scale topographic mapping of each selected route is purchased by contract negotiated with commercial firms. An aerial camera, having a distortion-free 6-in. focal length lens, is specified, as well as scale stable base film. Photography scale ranges from 1:4,800 to 1:12,000, depending on scale specified for map compilation.

The aerial photography specifications are patterned after the "Reference Guide Outline, Specifications for Aerial Surveys and Mapping by Photogrammetric Methods for Highways, 1958." The contractor is required to furnish two sets of contact prints and one photographic index of the aerial photography. In addition to black and white photography, aerial color photography is generally included, either at a scale of 1:6,000 or 1:12,000. This color photography has been used primarily by photographic interpretation for locating sources of suitable construction materials and as an aid in photogrammetric compilation of the map manuscripts.

Ground survey control work is performed by trained U. S. Bureau of Public Roads personnel. Placement of targets on the ground centered on markers of horizontal control points, at vertical control points in or near the corners of each stereoscopic model, and on property corners is completed before photographing each highway route. Normally, this targeting is adequate for the required mapping, but in some instances supplemental vertical control has to be measured to natural image points for short segments of each highway route. Although a variety of targeting materials has been used, white lime and white centerline striping paint have been most effective. Cross-type targets in which the center one-third of each leg is black, centered on the station marker of each control point, provide the contrast necessary for accuracy in orienting each stereoscopic model. The majority of surveys are incorporated in the State plane coordinate system by triangulation originating and closing on geodetic survey monuments for which the State plane coordinate positions are known or can be computed.

The State plane coordinates are adjusted for each survey project to a datum where differences between distances determined from plane coordinates on the maps and distances measured horizontally on the ground will not be larger than permissible by accuracies required in the basic control surveys, as 1:5,000 or 1:10,000.

The survey control traverse is measured by use of T-2 theodolites, 12-ft subtense bars, and electronic measuring devices. The elevation of stereoscopic model leveling points is measured by spirit levels in closed circuits or by measurement of vertical angles, using the subtense bar to obtain essential horizontal distances. Traverse azimuths, distances, and plane coordinates are computed by an IBM program written specifically for theodolite-subtense bar measured traverses.

Map manuscripts are compiled either by commercial firms under negotiated contract or by Region 9 personnel and equipment. Map manuscripts are normally compiled on a scale stable base polyester film, surface treated for drafting purposes. The plane coordinate grid is traced from a master coordinate grid sheet. For design purposes, compilation scale of the topographic maps is usually 100 ft to 1 in., with a contour interval ranging from 2 ft where the topography is nearly level to 10 ft where the topography is rugged. Areas presenting special design problems, such as bridge sites, are mapped at a scale of 50 ft to 1 in., whereas areas containing several feasible highway routes are mapped at a scale of 200 ft to 1 in.

For trial projection and design of the highway centerline on the topographically mapped route, ozalid prints from the map compilation manuscripts are used. The position of the centerline is plotted accurately on the compilation manuscripts using plane coordinates of its accurately computed PI, P.O.T., and curve points. Cross-section lines at 50-ft stations and intermediate points at right angles to the designed centerline are penciled on the reverse side of the transparent map manuscripts for ease in determining where dimensional measurements should be made.

The cross-sections are measured photogrammetrically on the stereoscopic models either by commerical firms engaged by negotiated contract, or by the photogrammetric unit of Region 9, using a Kelsh stereoscopic plotter and an Auto-trol digital scaler. Terrain measurement data obtained by contract are paid for on a mileage basis requiring an average of not less than a specific number of cross-sections per mile. With the Auto-trol scaler, the terrain data are electronically transferred successively from the stereoscopic model and punched into IBM cards in one operation. The punched cards are edited through an extensive IBM program to highlight any obvious human or machine errors. The corrected digital data are then tabulated for use in design.

In addition to using aerial photography for highway location and design, enlarged photographs (scale 100 ft to 1 in.) and semicontrolled photographic mosaics are used to advantage in the acquisition of rights-of-way and in condemnation hearings. One 3-dimensional model, constructed of styrofoam, has been used to choose the bridge site best fulfilling esthetic objectives.

The photogrammetric facilities and procedures are supplemented by:

1. Electronic measuring equipment (one set), delivered August 1, 1962.
2. A second Kelsh stereoscopic plotter for specialized mapping and training purposes.
3. Adoption and use of aerial color film negative photography on scale stable base. From this photography both black and white and color prints are made, thus eliminating need for the black and white film negative photography.

To date, the purchase of an airplane equipped with an aerial camera cannot be economically justified because (a) favorable weather and other conditions limit aerial photography throughout the greater portion of Region 9 to early spring and early fall, (b) the services of local commercial firms equipped for this type of work are readily available at economical prices, and (c) only about 175 mi/yr of highway surveys are made.

In using modern photogrammetric equipment and methods, junior engineers have excellent opportunities for training in efficient and effective surveying and design procedures and methods. This training is given in cooperation with the fully equipped electronic section, now part of the design section, and is supplemented by a complete program in all phases of highway location and design.

With approximately 400 mi of highway surveys completed by aerial methods, Region 9 personnel are aware of the numerous benefits obtainable from aerial surveys, including reduced survey costs, more complete and accurate data for design, and achievement of better highway locations for the construction funds available.

MICHIGAN STATE HIGHWAY DEPARTMENT PHOTOGRAMMETRIC ACTIVITIES

Clyde H. Brown, Photogrammetric Engineer
Michigan State Highway Department

The evolution of aerial surveying and photogrammetry within the Michigan State Highway Department has progressed at a slow steady, and fruitful pace throughout the past 10 yr.

In 1951 a Photogrammetric Section was established by the Department as a section of the Route Location Division. Early in 1961, the Photogrammetry Section was transferred to the Design and Survey Division.

Photography

The Department maintains up-to-date files of aerial photography covering the entire State. This photography was purchased from the U. S. Department of Agriculture and is at scales of 1:20,000 and 1:15,840. This coverage is used for area reconnaissance surveys and for preliminary route location purposes. The Soils Division also uses this photography quite extensively in photographic interpretation search for possible borrow pits. In addition, many miles of special photography has been obtained for specific purposes.

Photography for photographic mosaics to be used in route location studies and for photogrammetrically compiling large-scale maps for highway design is obtained from commercial firms on a negotiated contract basis. Each project flown and photographed is rigidly inspected and all photography is thoroughly checked for compliance with specifications based on those prepared by the Photogrammetry for Highways Committee, jointly sponsored by The American Society of Photogrammetry and The American Congress on Surveying and Mapping.

Photography flown for reconnaissance survey and photographic mosaic preparation purposes is generally accomplished with either an 8¼- or a 12-in. focal length cartographic camera at a scale of 800 ft to 1 in. All photography for design mapping purposes is obtained with a 6-in. focal length precision cartographic camera equipped with distortion-free lens, at scales of 250, 330, or 500 ft to 1 in., depending on type and nature of highway improvement for which a survey is required.

Michigan's weather is an important factor to be considered when planning aerial photography for the design-mapping program. In the lower peninsula, fall is not well suited to aerial photography for design mapping even though leaves are gone from the deciduous trees, because weeds, grass and corn present a problem by obscuring the ground. Spring is the ideal period for taking aerial photographs. Snow generally disappears in late April and trees are again in full bloom in late May. About 30 days are, therefore, available in which to accomplish all large-scale mapping photography, and of these, perhaps only 5 to 6 days present suitable aerial photography conditions.

Personnel and Equipment

The Photogrammetry Section is composed of a supervisor, an assistant who acts as ground control and compilation supervisor, two stereo-plotter operators, one operator trainee, three draftsmen and scribers, and one draftsman trainee.

The Department has two 5:1 projection ratio Kelsh stereoscopic plotters and a Santoni Stereo-Simplex Model III. If future programs warrant, a Benson-Lehner Terrain Data Translator and a second Santoni Stereo-Simplex Model III will be added.

Ground Control

All ground control is obtained by State forces. Each highway survey mapping project is targeted before photography. Two methods of placing targets on horizontal control points are used:

1. If time permits, the proposed centerline is staked on the ground and targets are set exactly on centerline at an interval of 800 ft for photography of 500 ft to 1-in. scale and at 400 ft for photography of 330 ft to 1-in. scale. Stationing of target points is obtained and coordinates computed for these points, along with P.O.T's, PC's, PI's and PT's. The elevation of at least five vertical control points is obtained per stereoscopic model.
2. To take advantage of good flying weather before survey parties can be assigned to the survey projects for centerline staking, an aerial photographic mosaic on which the proposed centerline has been delineated is used. Targets are set as near as can be ascertained to the proposed centerline. Later, field survey parties will make right-angle ties from the staked centerline to the targeted points.

Yellow oilcloth, cut into strips 9 in. wide and 8 ft long, is used for targets. Targets are anchored to the ground by No. 9 soft wire bent into the form of a croquet wicket. Ten wickets per target are used. After a survey project has been flown and photographed, the targets are retrieved to be used on another job.

Usually no attempt is made to target urban projects, as there is always finite detail which can be used for control points. All plane coordinate computations are done by electronic computers.

Research

Two research projects are planned in use of color photography for soils investigations. Research is also being initiated into the feasibility of constructing scale relief models of interchanges and other troublesome areas for design purposes and for presentation at meetings.

Photogrammetrically Compiled Cross-Sections

Comparison between field measured and photogrammetrically measured cross-sections has been completed on a 6-mi project. Results and conclusions have not been finalized. Preliminary comparison, however, indicates about a 2.5 percent differential.

Design Mapping

Topographic maps are compiled for design purposes at a scale of 100 ft to 1 in. with contours on a 2-ft interval in rural areas, and at a scale of 40 ft to 1 in. with contours on a 1-ft interval in congested land-use areas. In urban areas, planimetric maps are compiled and used extensively at a scale of 40 ft to 1 in. Planimetric maps are checked and annotated by survey parties in the field.

Between the spring of 1958 and 1961 the Photogrammetric Section contracted for, compiled, checked, and transmitted to our Design Division approximately 600 lineal mi of mapping for highway design.

PHOTOGRAMMETRY IN MISSISSIPPI

Aerial photography was first used in Mississippi in 1933. I. W. Brown, at that time Field Location Engineer, made an 18-mi location in the Delta area of Mississippi using aerial photographs borrowed from the County Board of Supervisors. In 1935, the first contract for aerial photography for highway usage was let. This was an experimental venture on seven different locations to represent average conditions to be found throughout the State. These photographs were used primarily for location work. A short time later, however, some of this photography was used to make a comparative cost test of measuring drainage areas. It was determined at that time that by using aerial photographs, the cost was approximately 15 percent of that of conventional methods of measuring drainage areas by field crews working on the ground.

In 1957, Mr. Brown was asked by the Director to set up a division for photogrammetry and electronic computing. Some trained personnel from other divisions were transferred and other personnel were hired and started on an extensive training program. Equipment was purchased and for all practical purposes, production was started in June 1958.

Aerial photography is used primarily for map compilation. The other important uses include:

1. Road inventory surveys;
2. Making general highway county maps;
3. Compiling detail drainage network sectional maps;
4. Making drainage area surveys;
5. Accomplishing section and property line ties for right-of-way work;
6. Making bridge location studies;
7. Completing river control and erosion studies;
8. Making municipal surveys;
9. Compiling property estimates and land usage maps;
10. Preparing photographic mosaics for special studies and highway route location work;
11. Compiling planimetric and topographic maps for special studies and highway design;
12. Making photographic enlargements for detail studies;
13. Photogrammetrically measuring cross-sections for computing earthwork quantities; and
14. Making reconnaissance surveys for accomplishing geodetic control surveys and recovery of station markers of control.

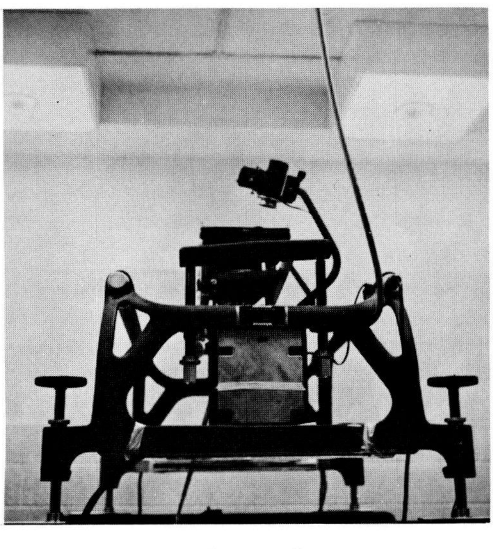

Figure 1.

The photogrammetric instrument section has three Kelsh stereoscopic plotters, as well as two Balplex tables with Multiplex aeroprojectors used exclusively for training purposes. Kelsh stereoscopic plotters are operated on two shifts and sometimes three, depending on the amount and emergency of the work load. One of the plotter rooms has been equipped with a variable intensity lighting system (Fig. 1). Four 300-w silver bowl, louvered fixtures are mounted in the ceiling above the stereoscopic plotter. These lights are controlled by variable potentiometers. The "incident light" measurement may be varied from 0.66 foot-candles (the output of the Kelsh instrument projectors) to a maximum of 48.0 foot-candles; the average building corridor is usually lighted to a 6 to 8 foot-candle intensity. Of the two photogrammetric instrument operators who have used this room, one started plotting at 2.75 foot-candles and is up to 3.25 foot-candles at the present time. The other operator started at 2.43 foot-candles and is now plotting with 4.67 foot-candles of light. Shift supervisors have a tendency to do their check work at a much lower intensity than the instrument operators. Using a comfortable amount of light may greatly reduce eye strain. In addition, it is a great timesaver, especially in measuring cross-sections, the dimensions of which are recorded manually.

The photographic laboratory has a Saltzman enlarger, Kargl copy camera, and a LogEtronic printer as the main components. All photographic processing, with the exception of aerial film negatives and two sets of contact prints, which are furnished by contract, is done in the laboratory. This work includes making extra copies of aerial photographs for field work, photographic mosaics, diapositive plates, map manuscripts, property boundary descriptions for right-of-way work, and various photographic enlargements for all phases of our highway work. A photographic mosaic is also printed on plan and profile sheets (Fig. 2).

Aerial photographs are used in all phases of field surveying of basic and supplemental control. All reconnaissance surveying and highway design are done by use of the aerial photographs and/or photographic mosaics. One interesting use of aerial photographs is the recovery program in which all existing control, both vertical and horizontal, in a township are identified and circled on a photographic mosaic (Fig. 3). These mosaics and identifying descriptions of the control points are bound by counties and sent to the project engineers. This procedure promotes the use of good control all over the State by the various construction districts. Control survey crews completed a 42-mi section of the Natchez Trace for right-of-way work (see Report of Region 15, U. S. Bureau of Public Roads, elsewhere in this publication). On conclusion of this work, a detailed report on procedures, cost, and other items, was prepared.

As all basic field control surveying is done, permanent station markers are set. Bench marks are set about 1 mi apart and the horizontal control station marker consists of surface station and underground mark, two reference marks, and an azimuth

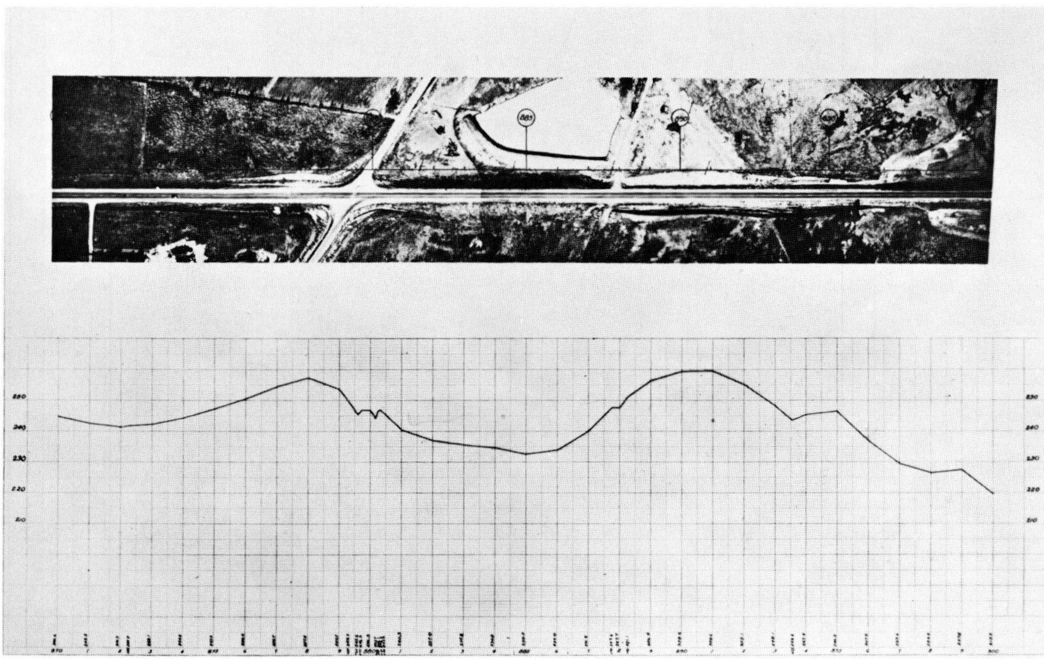

Figure 2.

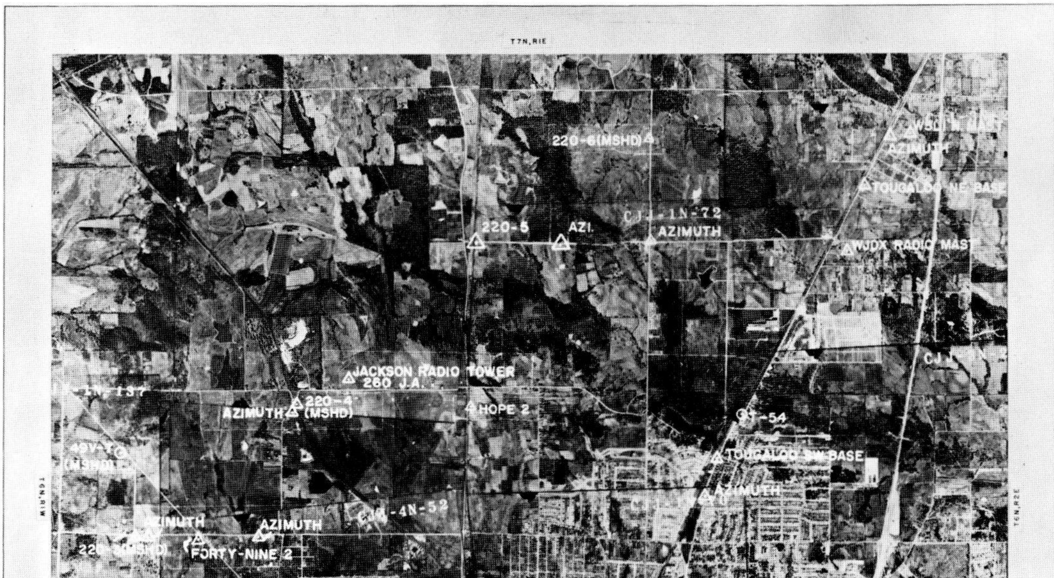
T7N, R1E
220-6(MSHD)
AZIMUTH
TOUGALOO NE BASE
220-5
AZI.
CJJ-1N-72
AZIMUTH
WJDX RADIO MAST
JACKSON RADIO TOWER
260 J.A.
220-4
AZIMUTH
(MSHD)
HOPE 2
T-54
TOUGALOO SW BASE
AZIMUTH
49V-7
(MSHD)
CJJ-4N-52
AZIMUTH
AZIMUTH
FORTY-NINE 2
49V-6(MSHD)
CJJ-1N-185
49V-5(MSHD)
AIR BASE CONTROL TOWER
V-167
AZIMUTH
T-167
X-167
HAWKINS
Y-167
AIRPORT BEACON
220-2(MSHD)
MILLSAPS
AZIMUTH
W5
U5
T6N, R1W
T6N, R2E
T5N, R1E
Prepared by
Photronics Development Division
Mississippi State Highway Department
Scale in Feet
0 1320 2640 3960
HINDS COUNTY
T6N, R1E

Figure 3.

mark. The field crews surveying vertical control use Zeiss self-leveling levels and K & E yard rods with foot-strips on the side for accuracy check.

The horizontal control surveying crews use Bilby aluminum towers, Tellurometer, and T-2 theodolites. The geodetic marker surveying program was planned for setting station markers along approximately 1,276 mi of the primary highway system.

Most aerial photogrammetric projects are targeted, using opaque white plastic material, except on sand bars where black is used. The material comes in 36-in. widths at $0.23/yd and is not retrieved because of the low cost. Specifications for setting targets, as well as for the complete photogrammetric work of each highway location and design project, from planning to the contract construction stage, are described in "Photogrammetry and Data Processing in Mississippi" by I. W. Brown, as prepared for the Committee on Electronics at the 47th Annual Meeting of AASHO, Denver, Colo., Oct. 1961.

A topographic map for highway location and/or design, at an appropriate scale, should be considered just as necessary for making an optimum location as any of the other tools now being used. The key to this concept is the word optimum. There is no doubt good highway locations can be, and are being made, without using large-scale topographic maps. Such a map, however, is a tool which, in the hands of an experienced engineer, provides an opportunity to determine and compare, in detail an almost limitless number of feasible locations at practically no additional cost, resulting in a highway that will be cheaper to build, cheaper to maintain, and provides the best possible traffic services.

PHOTOGRAMMETRIC ACTIVITIES OF THE PENNSYLVANIA DEPARTMENT OF HIGHWAYS

Charles E. McNoldy, Chief Photogrammetrist
Pennsylvania Department of Highways

Aerial survey methods, including photographic interpretation and photogrammetry, are utilized by the Pennsylvania Department of Highways in all appropriate phases of highway location and design. Utilization of these methods, however, is progressing cautiously due to some inaccuracies and unsatisfactory results encountered by the Department on early mapping projects. Adequate specifications and supervision of projects by professional photogrammetric engineering personnel have materially aided in attaining better accuracy in mapping for highway engineering purposes during the past several years and in developing more advanced techniques.

The initial significant expression of interest in photogrammetric methods, as an internal function of the Department of Highways, was purchase of a Kelsh stereoscopic plotter in 1955. Due to lack of trained photogrammetric personnel, little developed from this first step until January 1958 when the present organization came into being. The Photogrammetric Unit is currently organized in the Bureau of Design and reports to the Assistant Chief Engineer in charge of that Bureau.

Photography

The Department contracts with commercial photogrammetric firms on a negotiated basis for aerial photography. An aerial camera has recently been acquired to obtain oblique photography for planning purposes and for evaluating construction progress. The Department contracts for the use of an airplane and pilot, but the aerial photographer is a member of the Department's photographic staff.

Aerial photography to be used for mapping by photogrammetric methods is taken at scales of 1,000, 500, and 250 ft to 1 in. Specifications require the use of a distortion-free 6-in. focal length precision aerial camera. A contract with the U. S. Department of Agriculture was recently completed for aerial vertical photography coverage of the 67 counties of Pennsylvania at a scale of 1:20,000. Photographic enlargements of this photography at a scale of 660 ft to 1 in. were also purchased. The contact prints and enlargements are being utilized for area reconnaissance surveys for general highway and county mapping for planning, and for photographic interpretation in soils research. Large-scale aerial photography, taken from low flight heights, is used for engineering soils studies.

The Department's photographic laboratory is a section under the direction of the Special Assistant to the Secretary of Highways. The laboratory is not equipped to handle 9- by 9-in. size aerial photography, but may be expanded at a later date should this be warranted.

Ground Control

In September of 1961, the U. S. Coast and Geodetic Survey, under supervision of the Photogrammetric Unit, established monumented permanent geodetic survey station markers along the proposed routes of the National System of Interstate and Defense Highways in the Commonwealth. Begun in March 1958, basic control surveying was completed under contract for 1,151 mi of the highway network. The total amount expended for this work was $691,552.03, averaging about $600 per highway mile.

The U. S. Coast and Geodetic Survey field party established horizontal positions for control survey monuments set at intervals of 2 to 5 mi and determined elevations for vertical control survey monuments set at a 1-mi interval. All control survey monuments were set at distances of 500 ft to 0.5 mi from the actual or proposed centerline for the highway and were position identified on aerial photography furnished by the Department. These aerial photographs have been furnished the U. S. Geological Survey for use in planning control networks for 1:24,000-scale topographic maps to be compiled on a quadrangle basis by photogrammetric methods.

Department surveying personnel, in most cases, establish horizontal and vertical control for commercial photogrammetric firms when the mapping is for use by Department design personnel. All such control is extended from, and closed on, monuments established by the U. S. Coast and Geodetic Survey. Horizontal control positions are computed on the State plane coordinate system based on the Lambert Conformal Conic Projection. The Department has an IBM 650 electronic data processing unit for the reduction and adjustment of surveying data.

On consultant engineering contracts for location or design, the required mapping is usually the direct responsiblity of the consultant. Some consultants will establish the necessary mapping control, but generally commercial photogrammetric firms will complete all phases of the mapping program, including the essential control surveying as well as photography and compilation of maps by photogrammetric methods. All contracts written with the mapping clause, however, are subject to standard Department of Highways specifications for photogrammetric services and are closely supervised and inspected by Department photogrammetric engineering personnel. These personnel advise and assist the consultant engineering firms on photogrammetric procedures and methods and make available location descriptions and geodetic values of all newly established control survey monuments.

In rural or wooded area projects, photographic targets of white muslin cloth are set on the ground before photography flights. For 1:12,000-scale aerial photography targets are 3 by 10 ft, and for 1:3,000-scale aerial photography they are 1.5 by 5 ft. The targets are anchored to the ground with wood stakes and are retrieved for future use. Targets are set at an interval equal to one-fifth the specified photography flight height and on all existing permanently monumented triangulation stations and bench marks within the limits of photographic coverage. In densely wooded or steeply sloped areas, the points for the usual distribution of vertical control for map compilation by photogrammetric methods may also be targeted.

Personnel and Equipment

Current personnel include eight Kelsh stereoscopic plotter instrument operators and shift supervisors, three draftsmen, three survey computists, and four supervisors.

The unit is equipped with three Kelsh stereoscopic plotters. All are 5:1 projection ratio instruments with two projectors. Consideration is now being given to the feasibility of purchasing a three-projector model.

In March 1958, the Department purchased a MRA-1/cw Tellurometer and later a Model 4a Geodimeter for making distance measurements in control surveys. There are also a Wild T-1 and two Wild T-2 theodolites with complete essential accessories for making angular measurements, for polaris observations, and for night operations. The Department has Zeiss Ni 2 levels in each district office and in the photogrammetric unit for establishing vertical control.

Mapping for Design

Topographic maps for preliminary design are normally compiled at a scale of 200 ft to 1 in. with a contour interval of 5 ft. A scale of 100 ft to 1 in. for planimetric or topographic mapping with a contour interval of 2 ft is sometimes utilized in urban areas. Site mapping for bridge location and design and for drainage structure design is usually accomplished at a scale of 100 ft to 1 in. with a contour interval of 2 ft. An overlay depicting engineering soils classifications will probably be prepared for some of these projects. Maps for design and preparation of construction plans in rural areas are normally compiled to a scale of 50 ft to 1 in. with a contour interval of 1 or 2 ft. In urban areas a scale of 40 ft or 25 ft to 1 in. may be used for such design, depending on the complexity of the engineering problems.

Photogrammetric measurement of cross-sections has been authorized on a limited number of projects in lieu of delineating contours. The results thus far have been quite satisfactory. On one Interstate project, the cross-sections and earthwork quantities determined by this method have been accepted by the contractor for construction purposes.

Summary

During 1960, contracts were initiated on 25 projects totaling 253 mi of highway alignment. During 1961, contracts were initiated for aerial photography and printing of glass plate transparencies for Department mapping with Kelsh stereoscopic plotters on ten projects. Contracts have also been executed with several commercial photogrammetric firms for aerial survey work on a total of 123 highway miles.

During the 1962 spring season mapping was accomplished on eight projects for a total of 50 mi. During the 1962 fall program, aerial survey work was done on 17 projects totaling some 135.3 mi and including 45.2 mi of aerial photography at various scales, 14.5 mi of topographic mapping by photogrammetric methods at a scale of 50 ft to 1 in., and 75.6 mi at a scale of 200 ft to 1 in.

Contracts for these projects do not include topographic mapping or aerial photography requirements of the prime engineering contracts let separately for other work to consultant engineering firms for which surveys are also required.

FUNCTION AND TECHNIQUES OF THE PHOTOGRAMMETRY SECTION, TEXAS HIGHWAY DEPARTMENT

The Texas Highway Department recognized the value of photogrammetry as a tool in the location, design, construction, and maintenance of highway facilities during the early stages of the science's development and established a definite program of utilizing the various advantageous phases of photogrammetry. Since that time the program has developed into the creation of a separate section within the Highway Design Division, the employment of specialized personnel, and the procurement of equipment necessary for the completion of a highway project survey from the aerial photograph to the finished map. The Photogrammetry Section is directly responsible to the Chief Engineer of Highway Design and derives its authority through his delegation of duties. In recent months the section has undergone considerable expansion and improvement in anticipation of an even more complete utilization of aerial surveys by highway designers and planners within the organization.

Maps Compiled by Department

The Texas Highway Department, through careful deliberation of the subject, has not found it necessary to obtain aerial film negatives through the use of State-owned equipment and personnel. This phase of the total operation has been assigned to prequalified aerial photographic firms on a proposal basis under a set of standard specifications. No serious difficulties have been encountered under this system and it is expected the procedure will continue until a reevaluation demands use of an alternative method.

The Photogrammetry Section employs three Kelsh stereoplotters in the map compilation process. Scribing is used almost exclusively, and all plane coordinate grid systems are based, directly or indirectly, on the State plane coordinate system. The slotted template method of extending horizontal control has been used to a limited extent in mapping for the determination of drainage areas and other types of mapping projects where a low order of accuracy is acceptable. A sketchmaster instrument is usually used in the transfer of essential planimetric information from the photographs to the map compilation sheets.

Plans are being formulated toward the acquisition of an electronic measuring and digital recording instrument to be attached to the stereoscopic plotter as an aid in cross-section measurement and recording work. At present, this work is accomplished manually from the determination of elevations by the stereoscopic plotter operator to punching of the electronic computer cards.

In certain instances, where the size or importance of a project will allow, U. S. Department of Commerce photography has been used in the compilation of topographic maps. This has proved particularly valuable in reconnaissance or route location surveys that demand a flight height too large to produce a map suitable for use in the preliminary survey and design, and construction stages.

The varied nature of Texas topography and vegetation permits, in certain regions, topographic maps to be compiled from photography taken during the summer months. This advantage is utilized in photographing projects in these regions during this normally slack season.

Aerial photography flights from which only planimetric maps are to be compiled are made during any season and supplemented by field survey work where and if required. The setting of photographic targets on the ground over station markers of survey control points before photographing a highway survey project is desired, but in some cases basic horizontal control is established after the photography flying is completed.

All photographic processing, other than the aerial film negatives and the two sets of contact prints furnished by the contractor, is accomplished in the State's reproduction section. This section is fully equipped to handle all phases of the work, including the making of diapositive plates, enlargements of the photographs (both rectified and nonrectified), photographic mosaics (controlled and uncontrolled), reduction of map manuscripts (screened fully or partially) printed on plan-profile sheets or right-of-way plan sheets, and other related products.

In the past, basic field control has been established by each affected District office with the advice and assistance of a member of the Photogrammetry Section. On receipt of an Electrotape instrument recently ordered from the Cubic Corporation of California, a three-man field party, fully equipped for high order basic control surveying work, will be assigned this duty. Because a majority of the maps for highway design are compiled at a scale of 40 ft to 1 in., the electronic surveying device will be utilized to establish reference monuments approximately 1 mi apart that will be used as closure stations for transit-tape survey in staking the designed centerline of the highway. The transit-tape survey crew will set the photographic targets on points every 300 to 400 ft apart wherever photography of 200 ft to 1 in. scale is used and adjust the error of closure in the ground surveyed position of these points, if necessary, to each control survey station the Electrotape has occupied. The elevation of vertical control points near the corner of each stereomodel, and elsewhere as required, will be determined in the usual survey manner on the ground.

The District offices perform a field check and test profile analysis of the topographic maps as prints of the maps are delivered and inform the Photogrammetry Section of the results.

Maps Compiled by Photogrammetric Firms

In the event a highway project survey is to be developed by contract, proposals are requested from photogrammetric firms which have been prequalified by the State as to their abilities and facilities. The request is accompanied by a set of standard specifications pertaining to the acceptable quality of photogrammetric work in general and a set of special specifications setting forth conditions and standards applicable to the particular project.

The contractor is responsible for the photography, all compilation products, and the field control. The Photogrammetry Section checks the manuscripts on a stereoscopic plotter while the District field offices conduct a separate on-the-ground evaluation as delivery is made. The District field office is informed as to the results of the stereoscopic plotter checking and either returns the map sheets to the contractor for correction or accepts them as meeting the requirements of the specifications.

Special Projects

A procedure has been established in obtaining detailed right-of-way information from maps compiled photogrammetrically at the large scale of 20 ft to 1 in.[1]

Research is being conducted into the possibility of utilizing a six-projector Kelsh stereoscopic plotter instrument in bridging horizontal control. The recent delivery of a three-projector Kelsh instrument should facilitate this research.

A system of reducing the aerial photographic image to 35-mm strip film and the projection of a three-dimensional image on a screen through the use of two projectors remotely controlled from a single source is being studied both for design use and for demonstrations at public hearings.

Color photography has been examined to a limited extent for feasibility in differentiating soil conditions, geological formations, types of ground cover, etc. No definite program for its general use has been established.

An attempt is presently being made to design an image projecting machine, manually operated, that will determine the azimuth and degree of tilt, scale, and crab of a photograph through the use of opaque templates.

PHOTOGRAMMETRY IN ARIZONA HIGHWAY DEPARTMENT

The Photogrammetric Division of the Arizona Highway Department was inaugurated in October 1957 with a staff of six men selected from existing personnel with varying experience in utilization of photogrammetric methods. Equipment consisted of a KEK plotter, two vertical sketchmasters, a slotted template cutter and an assortment of used drafting tables. The initial purpose of the new division was revision and modernization of the small-scale county maps which had been made a number of years previously and were incomplete and inadequate.

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[1] Henry, H. A., "Development of Photogrammetric Methods for Right-of-Way Operations in Texas." HRB Bull. 283, pp. 39-48 (1961).

Existing aerial photographs secured through the Army Map Service, augmented where necessary by new photography secured through contract, were used in preparing map manuscripts for the revisions. By radial line plot, originating and closing on existing U. S. Coast and Geodetic Survey, Forest Service, and Government Land Office established basic control, supplemental horizontal control was established for mapping with the aid of vertical sketchmasters and the KEK plotter.

Three of the existing 13 counties within the State have been mapped, comprising some 15,227 sq mi. Work on the remaining counties is in various stages of completion. Maps are lithographed in three colors at a nominal scale of 0.5 mi to 1 in. Selected areas with more detail are shown at a larger scale.

As county mapping progressed and additional funds became available, the scope of the work of the Photogrammetric Division expanded to include larger scale topographic mapping for highway reconnaissance surveys and for highway location, which now forms the greater part of the work. Two standard two-projector Kelsh stereoscopic plotters were purchased and in 1960 an additional three-projector model was added. Until recently all photography was secured by contract with outside firms. Ground control has been developed, placing targets on markers of control points before the aerial photography is taken, by cut-and-try methods. Wild T-2 theodolites, Zeiss self-leveling levels, subtense bars, steel tapes, and related equipment were used.

The Photogrammetric Division has five ground control survey crews working under control survey engineers. Present personnel total 64, including 5 map compilers working two shifts on the three Kelsh instruments. Both Tellurometer and Model 4 Geodimeter are now part of the ground control surveying equipment. The Tellurometer is used for measuring distances of more than 0.5 mi, and the Geodimeter for the short measurements and for positioning from the maps the designed centerline of each highway on the ground. Targets for marking control points are generally constructed of Firestone Velon plastic sheeting 0.003 in. thick, available in 36-in. wide rolls. This material shows up well in the photography and is easily placed using lath, stakes, and large spikes. White traffic-line paint is used to pre-mark targets on existing paved roadways where necessary. Whitewash and cement mixtures have too short a life for use on Arizona highways under modern traffic conditions.

Maps, both planimetric and topographic, are generally compiled at a scale of from 50 ft to 1 in., with a contour interval of 2 ft, to a scale of 1,000 ft to 1 in., with a contour interval of 25 ft. The larger scale maps are used in detailed design of interchanges and bridges and the smaller scale maps are for reconnaissance purposes to determine and compare route alternatives and to select a route for preliminary survey and design. Generally a scale of 100 ft to 1 in. with a contour interval of 5 ft is used for designing the highway location, and a scale of 400 ft to 1 in. with a contour interval of 10 or 20 ft for the reconnaissance work, although highway locations are sometimes established by use of the smaller scale maps.

Wherever possible, basic control is originated and closed on station markers in the State plane coordinate system of the U. S. Coast and Geodetic Survey. This procedure not only serves to position stereoscopic models for the mapping but is a positive check on the accuracy of the work performed. Map compilation is done on Stabilene or similar material, and each manuscript map is printed directly for use in highway design and preparation of detailed construction plans. Computations for the ground survey control and its adjustment are done by a Univac Solid State 90 Computer in the Computing Section.

After the highway centerline has been established in the design processes, the plane coordinate computed position of essential points, such as PI and intermediate P.O.T., are established on the ground with the Geodimeter from the previously established horizontal control points, and the elevation of these points is measured by use of spirit levels. The designed centerline has been accurately plotted on the topographic maps using plane coordinate computed points, stationing determined, and, after resetting the photographic glass plates in the Kelsh stereoscopic plotter, cross-sections are measured and digital dimensions thereof are used in the electronic computer for ascertaining grading quantities. Later, the centerline is staked on the ground and permanent bench marks are established. At the present time, no attempt has been made to use photogrammetric techniques for determining construction pay quantities.

A Cessna 185 airplane was recently purchased, and a Kargl converted K17 camera is being installed. It is expected all aerial photography in the future will be taken by and processed within the Department, thus making the Photogrammetric Division self-contained.

USE OF PHOTOGRAMMETRIC AND ELECTRONIC PROCESSES BY THE INDIANA STATE HIGHWAY COMMISSION

In November 1959, approval was given for the organization of the Bureau of Photogrammetric and Electronic Processes within the Construction Division of the State Highway Department of Indiana. An aerial photographic laboratory had already been set up in 1956. The new Bureau had as its responsiblity the performance or supervision of the following:

1. All aerial photography, either vertical or oblique, and requisite laboratory work of processing, printing, enlargement, mosaic preparation, and graphic arts reproduction associated therewith;
2. Any ground photography of a special nature requested by personnel of the Central Office, wherein the nature of the assignment justifies the services of a qualified photographer and the use of professional equipment;
3. The performance of any graphic arts, photostat or photographic copy work possible within the scope of the equipment and facilities of the photographic laboratory;
4. The preparation by photogrammetric methods of any topographic or planimetric reconnaissance or design maps using the Kelsh stereoscopic plotters;
5. Preparation, development, utilization, or modification of computer programs, and their application and processing in the IBM 650 computing equipment, for use in the design and construction of roads and bridges, traffic studies, route location, etc.
6. The maintenance of a complete file of the latest available aerial photographic coverage of the 92 counties of the State, as acquired from the Agricultural Stabilization and Conservation Service (ASCS) of the U. S. Department of Agriculture.

Equipment

The Bureau maintains a 1956 Piper Apache PA-23 (5 place, twin engine) modified for vertical camera equipment and oxygen equipped. Among the cameras are one each of a K-17C 6-in. Metrogon f/6.3; a K-17B 12-in. Aerostigmat f/5.0; a F-56 8¼-in. B&L Altimar f/4.0; a Speed Graphic 4 by 5 162-mm Optar f/4.5, 90-mm Raptar wide angle f/6.8; and Calumet view 4 by 5 135-mm Schneider Symmar f/5, 90-mm Schneider Super-Angulon f/8. Darkroom equipment includes cut-film dryers, various printers and enlargers, and a camera test bench. Sinks and tanks are, wherever possible, stainless steel to minimize corrosion. The three darkrooms are equipped with Kodak Utility Model Safelights and appropriate filters.

Laboratory Personnel

In early 1957 an engineer of Photogrammetry was engaged to direct procurement of equipment and supplies and to initiate operation of the photographic laboratory. Subsequently, four highway technicians and a photographic laboratory supervisor were hired. The maximum number of employees was reached in early 1961 when the laboratory employed a total of 13.

Outline of Procedures

1. A single strip reconnaissance flight at a 1,600 ft to 1-in. scale will give a 14,400-ft width of coverage, and 3 sidelapped flights at an 800 ft to 1-in. scale will give

a width of 18,000 ft. Considerably more work is involved in providing the latter coverage. It is, therefore, suggested that for expediency and economy the 1,600 ft to 1-in. contact scale photography be used wherever possible. Supplemental photography for mapping special areas or conditions requiring a ratio of enlargement beyond that possible at the 1,600 ft to 1-in. scale can be taken at the same time, at either 800 or 400 ft to 1-in. scale, provided such requirements are clearly stipulated at the time reconnaissance survey photography is requested. Normally, reconnaissance survey photography is not too critical with regard to foliage and vegetation, but if such is objectionable, it must be taken when foliage and vegetation are not present.

2. The Planning or Location Department should be provided with 9 by 9-in. contact stereoscopic points, a photographic index and a 24- by 36-in. uncontrolled mosaic at the scale of 800 ft to 1 in., compiled from the photography. If sufficiently current and acceptable ASCS photography is available, contact scale prints and photographic indexes can be obtained from this agency without reconnaissance flight photography. Any photography intended for eventual mapping in the Kelsh stereoplotters must be taken with one 6-in. focal length aerial camera, because the stereoplotters are equipped to handle only such photography.

3. Planning or Location Department uses 9- by 9-in. contact scale stereoscopic coverage, 24- by 36-in. photographic mosaics, U. S. Coast and Geodetic Survey quadrangle size topographic maps, ASCS photography coverage, etc., in route location surveys. If topographic maps issued by the various Federal agencies are not available or do not particularly suit the needs for intelligent determination and comparison of route alternatives, the Planning or Location Department may have to request the preparation of topographic maps of the area involved by the photogrammetric instrument operation section. These maps could be compiled from the 1,600 ft to 1-in. scale reconnaissance photography taken with a 6-in. focal length aerial camera and using the requisite horizontal and vertical control. Such photography makes it possible to delineate contours at an interval of 10 ft at a map manuscript scale of approximately 400 ft to 1 in. If a pertinent area only need be mapped, instead of the entire photography coverage area, considerable time could be saved in the preparation of such reconnaissance-type maps. With this exception, and that of compiling topographic maps for bridge design, contours will not be delineated in any mapping accomplished by photogrammetric methods.

When the most feasible route location has been determined, the Location Department will order one of its survey parties into the field to stake the highway centerline designed on this route and to establish horizontal and vertical control for photogrammetric mapping. The survey party shall obtain all other pertinent and essential information, with the exception of measuring cross-sections and the recording of any topography that would be visible in aerial photography. At this stage the survey party may find it necessary to adjust the alignment given to them by the locating engineer. They will also note any detail of consequence required by the Design or Construction Departments that would not be visible in the aerial photography, such as pipelines, box culverts, underground drainage, utilities, property lines, and property owners. After inspection and approval by the location engineer, the complete notes of all field surveying shall be furnished to the Photogrammetry Section, along with a flight plan map or aerial photographic mosaic on which the staked alignment has been accurately plotted using plane coordinates.

4. The Kelsh stereoscopic plotter section will set targets on all horizontal control points and required centerline points that will be visible and identifiable on the large-scale photography.

5. A single low level flight will be made over staked and targeted centerline, and vertical photography will be taken at the scale of 250 ft to 1 in., providing a strip band of coverage 2,250 ft wide. Planimetric maps will be compiled at the design scale of 50 ft to 1 in. This scale, which requires considerably more photographs, photographic laboratory work, field control surveys, and stereoplotting than would a scale of 100 ft to 1 in., is justified by the increased accuracy attainable in the subsequent measuring of centerline profile and cross-sections and the stereoplotting of planimetric detail.

This aerial photography flight must be made when foliage and vegetation are not present, unless their presence is of so little significance that they would not seriously affect accurate delineation of planimetry and measurement of the ground surface. In the latter instance, this photography flight could be made at any time the weather permits, but the locating engineer's survey party would have to provide cross-section data and topography information in areas of foliage or vegetation where such would prevent accurate use of the stereoscopic plotter. In either instance, this photography flight should be made as soon after the survey staking and ground targeting of the centerline hubs and horizontal control points as possible so that the targets will be conspicuously clean and visible on the photography.

6. The Kelsh stereoscopic plotter section must be provided with a photographic index of 9- by 9-in. contact prints and glass transparencies of the 250 ft to 1-in. scale photography.

7. The stereoscopic plotter section then obtains the minimum necessary vertical control, not to exceed six points for each stereomodel, to be used in the photogrammetric operations.

8. The stereoscopic plotter section prepares a 50 ft to 1-in. scale planimetric strip map, in 24-in. width roll form, on dimensionally stable material. The minimum width of mapping each side of the highway centerline is determined by the Location and Design Departments and such width is controlled by the right-of-way required and proximity damage or by the maximum cross-section dimensions of the roadway and roadside developments.

Planimetry on the maps will be complete in all details, indicating distances along and out from centerline of all objects such as trees, buildings and other existing structures, drainage features, fence and property lines, property owners, and any other information needed by the design engineers in designing the highway and preparing construction plan-profile sheets.

If the design engineers prefer to have map planimetry furnished at a scale of 100 ft to 1 in., particularly in rural areas, accurate laboratory reduction of the 50 ft to 1-in. scale mapping can readily be provided, or any portion may be enlarged to a scale of 25 ft to 1 in. Because of the considerable photographic laboratory work involved in this reduction or enlargement, the 50 ft to 1-in. map scale should be used wherever possible.

9. Immediately following completion of the planimetry compilation and establishment of centerline stations and plus points necessary for photogrammetric measurement of cross-section data, spot elevations along centerline and perpendicular thereto along cross-section lines will be measured directly from each stereoscopic model and recorded in such form as may be required by the Design Department and the Electronic Computation Section.

10. All data will be furnished the Design Department for use in design and preparation of construction plan-profile and cross-section sheets. The dimensional data will also be furnished to the electronic computer section for the preparation of the first group of punched cards of centerline profile and cross-sections.

11. As soon as the Design Department has established highway centerline grades on the profile, controlling elevations of the grade lines will be furnished to the Computer Section in such form as they may require for the preparation of the second set of punched cards based on the established grades, which, when processed with the first set containing existing ground data, will result in the computation of earthwork quantities. Several trial attempts may be required in this procedure before the highway gradient can be established.

12. Until such time as there is electronic plotting equipment, plotted cross-sections, if required, will have to be provided by the Design Department. Plotted cross-sections are not required for computation of earthwork quantities. If they are expected as part of the construction plans by the construction forces and by the contracting organizations, they will have to be plotted by conventional methods.

13. The same general procedures are applicable in furnishing aerial photography, in compiling topographic maps, and in electronic computing for location and design of bridges by the Bridge Design Department. The same 50 ft to 1-in. scale maps compiled from the 250 ft to 1-in. scale photography can be accurately enlarged to the 30 ft to 1-in. scale customarily employed in bridge design. To provide a plotting scale of

30 ft to 1 in. directly on map manuscripts under the stereoscopic plotter would entail use of a flight height of only 900 ft above the ground. Over exceedingly rough topography and throughout urban areas where air traffic is heavy, this flight height would impose a serious safety problem. Wherever relief within each stereoscopic model does not exceed 220 ft, the flight height must, in all cases, not be less than four times the height of relief that will appear in each successive stereoscopic model to be used in photogrammetrically compiling maps and in measuring profile and cross-sections. Location conditions will, therefore, determine the photogrammetric methods by which the 30 ft to 1-in. scale maps can be provided.

14. After construction has been completed, photogrammetry and electronic computation can again be employed in the determination of as-constructed pay quantities. Photography taken for this purpose would also provide a photographic record of the project as constructed for future reference.

15. Additional Services:

a. Electronic computation, in addition to computing earthwork quantities without the necessity of plotting cross-sections, has a limitless field of application in design and in solving construction problems, such as designing vertical and horizontal alignment, making traverse computations, determining profile grades, making ditch grade analysis, designing interchange ramp profiles, accomplishing horizontal and vertical curve computations, ascertaining bridge geometry, and completing all phases of design, making traffic analysis, computing right-of-way metes and bounds descriptions, and making bid tabulations. Actual production is now being accomplished on several of these applications.

b. On completion of right-of-way plans by the Design Department, photographic mosaics can be assembled, copied, and printed from the reconnaissance, ASCS, or special photography.

c. Special aerial photography, either vertical or oblique, can be provided for such usage as right-of-way delineation and evaluation, traffic analysis, interchange design, borrow pit quantity determinations, maintenance, soils and drainage determinations, route location determinations, preliminary survey of selected route, and illustration and public information.

Right-of-Way Photographic Mosaic Requirements

For each right-of-way project, one set of photographic film reproduction negatives, 24 by 36 in. each, of an aerial uncontrolled photographic mosaic is required at a scale of 400 ft to 1-in. in rural areas and at a scale of 100 ft to 1-in. in urban areas. Said negatives shall be prepared on a continuous tone or lithographic emulsion coated polyester film base material, shall be direct reading with the emulsion side down, and shall have a matte or other surface on the top or direct reading side on which black opaque ink may be readily applied and retained without chipping or flaking under continued use. The acceptance by the State of this material, such as DuPont Cronaflex, shall be conditioned by the ability of the engineer to provide, to the satisfaction of the State, a rendition of tonal gradation on such material which will produce quality blue prints from the negative.

The mosaics specified may be prepared from either (a) the latest currently available ASCS aerial photography, (b) other existing aerial photography produced by a qualified aerial survey organization within the past 3 yr, or (c) new photography taken by or on the order of the engineer specifically to obtain the coverage required. Any such photography especially that of urban areas, shall depict acceptably current conditions of civic and personal property or other improvements within the area involved, and shall have the photographic image quality essential for satisfactorily fulfilling all needs of the State. The engineer shall submit his request for the proposed photography for approval by the State before preparation of the photographic mosaics.

In no event shall the ground area coverage of the reproduction negatives, in the 24-in. dimension, be less than 9,600 ft wide at the 400 ft to 1-in. scale, nor less than 2,400 ft wide at the 100 ft to 1-in. scale.

The reproduction negatives of the photographic mosaic shall be sufficiently image matched and end lapped between successive sheets to provide a matched continuous strip of each right-of-way project when blue-printed, trimmed, and spliced together.

The reproduction negatives shall have the following information indicated:

1. The centerline of the selected and surveyed route, positioned approximately in the center of the 24-in. dimension, with notations as to centerline stationing, degree of curvature on portions of centerline on curve, and a north point;
2. A dotted line indication of the entire property ownership both sides of centerline, and of all property adjacent to or bisected by the centerline;
3. The right-of-way line, as established, both sides of centerline,
4. The name of each property owner, or owners involved,
5. The specific acreage involved in the right-of-way taking, the separation, and the residue;
6. Any adjacent land survey section corners falling within the coverage specified, both sides of centerline, with all four sections indicated in a small circle;
7. Appropriate designation of all county lines, and all State and county roads, streams, and ditches; and
8. An appropriate title designation on each reproduction.

Summary

Photogrammetry has been employed on five road projects in which all planimetry and spot measured cross-section position and elevation points have been furnished to design squads. None of these jobs has yet progressed to the point of being placed under contract. Other stereoscopic instrument measurement work has been performed on borrow pits, for interchanges, and for a small amount of route location survey and design work.

The major portion of the aerial work, however, leads to preparation of photographic mosaics for route location by the Planning and Location Departments. Photographic indexes and stereoscopic print coverage are always provided. Oblique, public interest photography is also taken as required for the public relations department.

FUNCTION AND TECHNIQUES OF THE PHOTOGRAMMETRY SECTION, KANSAS STATE HIGHWAY COMMISSION

In 1957, a committee of five engineers was formed by the State Highway Engineer of Kansas and given the responsibility of reviewing reports of visitations made to States having organizations utilizing photogrammetric equipment, making inquiry and investigations, and finally submitting a report suggesting steps to be taken by the Highway Commission of Kansas with regard to the use of such equipment within its organization. The results of this action found the first section of the Department of Electronic Computer, Aerial Surveys and Photogrammetry organized in late 1957 with the training of personnel taken from the various existing departments in a special programing school. Electronic data processing equipment was ordered. Late in 1958, the second section was started. Again personnel were taken from existing departments for training in photogrammetry and its allied functions.

Since this time considerable growth has occurred. An organization chart of the department is shown in Figure 4. It should be noted that dual roles are being assumed by several individuals. The assistant to the head of the Photogrammetry Section (Supervisor of Aerial Surveys and Photogrammetry) is also the pilot of the plane. The Supervisor of the Photogrammetry Laboratory is the aerial cameraman. Until recently, the head of the Computer Section was also listed as a pilot and both photographers in the Photogrammetry Laboratory are alternate aerial cameramen. The system of dual roles has proven very effective in the organization of the department.

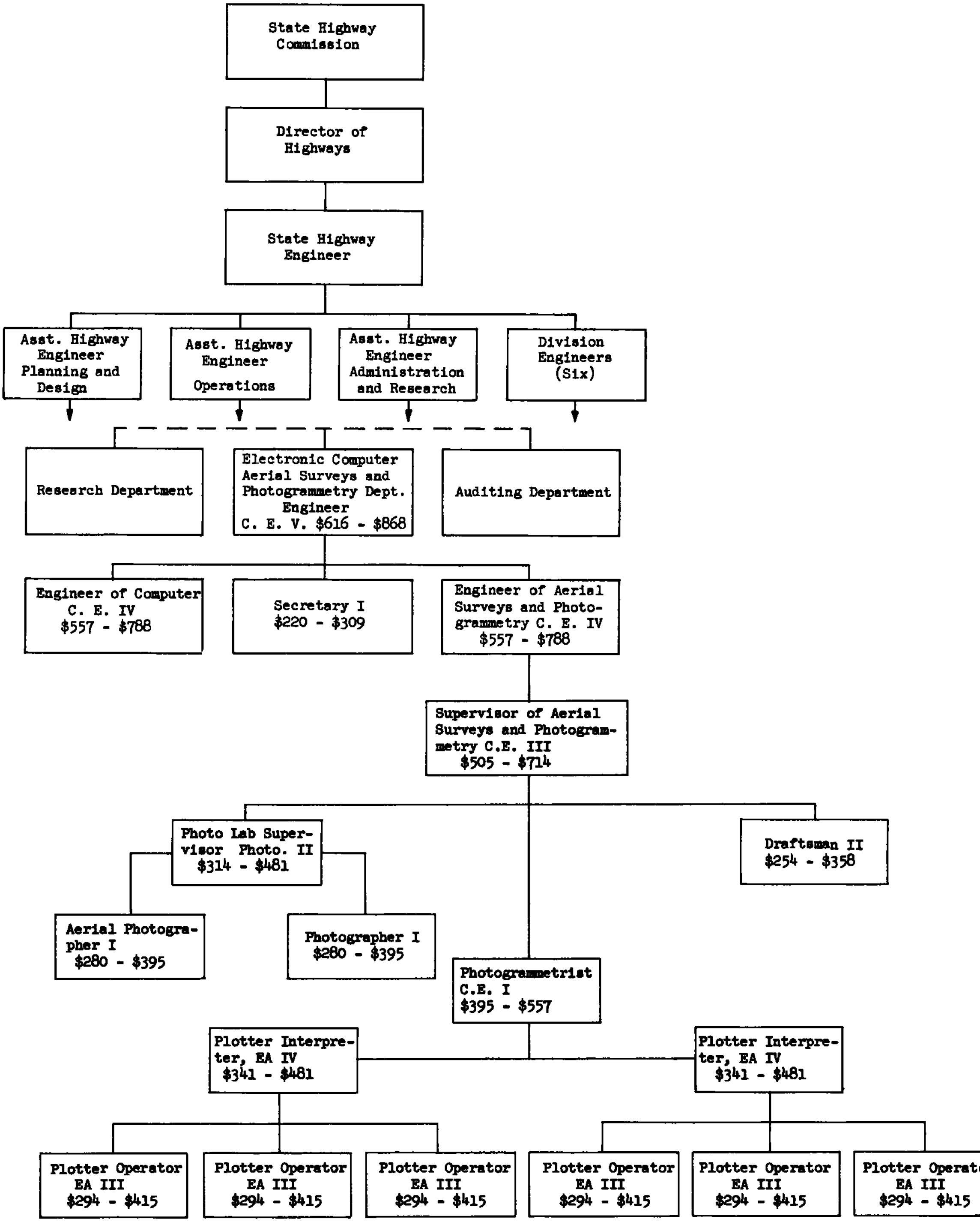


Figure 4. Organization of State Highway Commission of Kansas, pertaining to the Photogrammetry Section, with salary ranges effective July 1, 1962.

TABLE 1

USE OF STATE-OWNED AIRCRAFT[a]

Year	Photogrammetry		Personnel Trans.		Total		Costs ($)	
	Hr	%	Hr	%	Hr	%	Dept.[b]	Oper[c]
(a) Yearly Total								
1959	151.0	55.33	121.9	44.67	272.9	-	2,020.20	2,020.20
1960	178.8	57.07	134.5	42.93	313.5	-	1,502.40	4,225.50
1961	275.7	93.84	18.1	6.16	293.8	-	1,411.20	3,969.00
Total	605.5	68.80	274.5	31.20	880.0	-	-	-
(b) Monthly Averaged[d]								
1959[e]	12.58	55.32	10.16	44.68	22.74	100.0	-	-
1960	14.90	57.07	11.21	42.93	26.11	100.0	-	-
1961	22.98	93.83	1.51	6.17	24.49	100.0	-	-

[a]For period April 1, 1959 to Dec. 31, 1961.
[b]Rates for 1959, 1960, and 1961 are $7.40, $4.80, and $4.80, respectively.
[c]Rates for 1959, 1960, and 1961 are $7.40, $13.50, and $13.50, respectively.
[d]Total average use = 880.0/33 mo = 26.66 > hr/mo.
[e]For 9 mo.

Aerial Photography

In April 1959, Kansas purchased a Cessna-182 aircraft, modified for a Wild RC-8, 6-in. focal length camera. Since that date, the aircraft has flown 880.0 hr (Table 1). It is used for personnel transportation as well as for photography. The cost of the aircraft, auto-pilot, radio equipment, and modification was $22,736.59 and the cost of the Wild RC-8 camera was $17,150. Immediately before the purchase of this equipment, a total of $13,581 was expended for photography on a contract basis. Several previous projects (by contract) for mapping using photogrammetry did not prove successful, and the process within the Commission was initiated under an air of distrust of the system and is proceeding at a cautious pace. The first projects were small, experimental and limited in scope. The results were not successful in the area of accuracy but formed the stepping stones to much better work being performed at the present time.

A review of the operation to early 1962 indicates that the actual operation costs of the aircraft are less than the total allowed by rate. The rate does not include the cost of the hangar and insurance for the aircraft, but does include all other costs that can be applied directly to its operation. The rate of depreciation is set to reduce the original cost of the equipment to one-half of its original value in 10 yr with a monthly operation of 25 hr.

The present practice is to photograph all major projects before beginning design and preparation of highway construction plans, again after construction has been completed, and in some cases every several months or years after completion. Several scales have been used; however, the present practice is to fly all planning photography at a flight height of 6,000 ft giving contact prints a scale of 1,000 ft to 1 in., and all design photography at a flight height of 1,500 ft giving contact prints a scale of 250 ft to 1 in. Mapping projects usually involve these same scales. There is occasion to use photography having a scale of 400 ft to 1 in.; for determination of highway construction cost estimates, some projects are flown at heights of 3,000 and 12,000 ft. The section is, at the present time, attempting to photograph all cities, State institutions and parks during routine aerial photography flights. A card index file has been developed along with a set of maps showing the coverage of photography within each county. These maps are reproduced and distributed on a quarterly basis to all users of the photography. A master is kept current in the section at all times. The section also maintains a complete file of all oblique photography taken. These are single photographs and are usually taken to show a specific feature. They are used extensively for public relations, progress reports, public hearings and similar uses. Over 20,000 photographs have been taken, and 511 areas have been covered, varying from strips taken along the proposed improvement to the mapping of areas. Over 20 percent of the towns and cities have been photographed, with most of the photographs taken for this purpose within the last 6 mo.

The section is currently photographing 16 drainage areas in cooperation with the U. S. Geological Survey. Rainfall and runoff data are being accumulated. The photography is being used to determine the drainage area to within 0.5 percent of its true value. Various land-use and cover factors will be determined from the photography and will be correlated with the runoff data to produce factors for hydraulic computations which will be more reliable than those used at the present time. Each of the drainage areas includes a gaging station. The photography for this project is to be completed before the end of the fiscal year.

Several proposals are being considered to initiate a project for the photographing of the entire State on a 5-yr plan. This photography will be used primarily for the study of land use, materials investigations, the location of all sources of materials and for preconstruction photography of all highway projects. A secondary use of this photography will be by the Planning Department in the 5-yr map revision program. Post-construction enlargements for legal cases would also originate from this photography, as well as long-range planning of projects, establishing route locations, and determining drainage areas.

The principal months for flying to take aerial photography in Kansas are March, April, and May in spring; and September, October, and November in fall. The sparse tree cover in the western portion of the State allows photography during any season when snow does not cover the ground. Actually, some aerial photography flying has occurred during winter months when there was little snow cover. There is, therefore, the possiblity of year-round activity. If possible, all flights are planned with several areas indicated as primary photographic missions and several areas as alternate photographic missions. The total mission planned is actually more than could be covered in one day. If the weather prevents activity in one area, alternatives are considered. Through this process, the section has made only two flights since early in 1959 when no photography was obtained. Charges are computed on a prorated basis and the cost of photography for any one project is, therefore, reduced within the total operation.

Photographic Processing

All aerial film is developed and printed in the section's Photographic Processing Laboratory. This laboratory was started and actually in operation before the section was obtaining its own photography. A Wild Aerial Film Developing Kit and a Wild Aerial Film Dryer were purchased at a cost of $2,220. A copy camera was constructed which can use either a 47.5- 30-, 19-, or 9.75-in. focal length lens. A contact paper and glass plate photographic printer was also constructed by the personnel of the section at a cost of around $150. Equipment such as a print dryer, two sets of Color Tran Line-lights, Nu-Arc Vacuum Frame, timers, safe lights, and other items were purchased. The total cost of the laboratory equipment including the aerial camera, office equipment, and furniture was $29,827. Although some items have been added since these purchases, the basic equipment still remains. The addition of an automatic dodging printer and a rectifying enlarger is being considered.

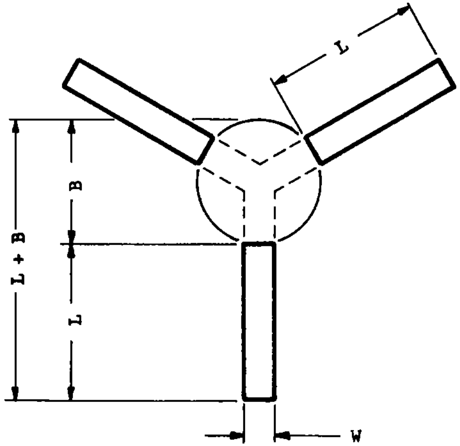
All negatives are properly numbered according to geographic location within Kansas, date of photography, and flight height. A cross-index arrangement and file system locate a set of prints and the roll of film easily. The system was designed to fit with other systems currently in use in other departments of the Highway Commission.

Over 50 percent of the operation of the photographic laboratory is service production of plans and photographs for other departments. One of the important services performed is the production of the negatives and negative overlays used in printing county maps of Kansas. Perfect matching is required on this photography because the maps are produced in color and the overlays must register with the base map. These maps are produced by the Planning Department, reproduced by the Photogrammetric Laboratory, and printed at the State's plant.

Ground Control

Kansas uses both a picture point control and a target marking of control procedure. All surveys are made by the regular Design Department's survey crews or by the resi-

For targets made of lime, plastic, or similar material.



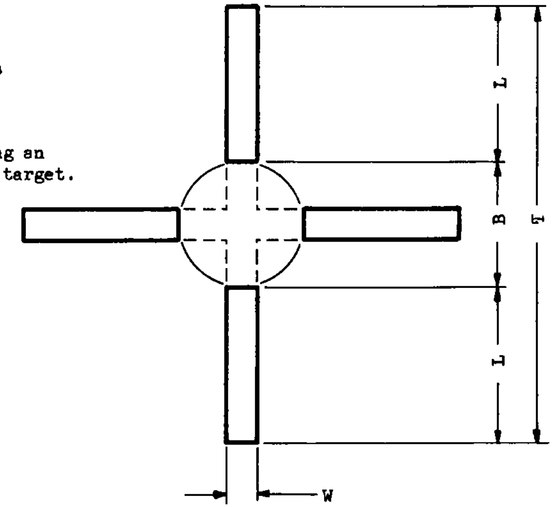
Typical target for marking pass points of known elevation

TARGET DIMENSIONS

Flight Height (feet)	L (feet)	B (feet)	W (inches)
900	1½	1	3
1200	2	1	4
1500	2¼	1½	5
1800	2½	2	6

Figure 5

A target for horizontal control points, the legs of which are constructed of lime to the dimensions T, L, and W. The center portion at the control point has a diameter B which is not limed, giving an open effect to the cross target.



Plastic strips having the width W and length L are available. This target, when constructed of plastic strips, is used on all station markers of horizontal control and may be used on points of vertical control.

TARGET DIMENSIONS

Flight Height (feet)	T (feet)	L (feet)	B (feet)	W (inches)
900	4	1½	1	3
1200	5	2	1	4
1500	6	2¼	1½	5
1800	7	2½	2	6

Figure 6

dent engineer. When a survey crew was not available from these sources, a crew made up primarily of photogrammetric instrument operators has been used. Usually a stereoscopic instrument operator is sent to assist a crew, if the survey for ground control is the first survey of this type that the crew has attempted. The usual method of control is that of using a baseline or centerline as the horizontal control and setting elevation pass points at an appropriate distance from each side of the line for vertical control. A profile of the line is also measured. A manual was produced by the section to guide field survey crews in control surveys. Pages from this manual are shown in Figures 5 and 6.

Some research was conducted by the section to determine a good procedure for the setting of targets. The size and material of the target were the primary interest of this research. Lime has been used for some targeting. Current practice, however, is use of Firestone Velon plastic sheeting, 0.003 in. thick (Fig. 7). Cost per target using this material is about $0.15. The target itself consists of four strips, 6 in. wide and 3 ft long, laid in a cross having an open center of about 18 in. The use of an open "Y" for points of elevation has proven quite successful.

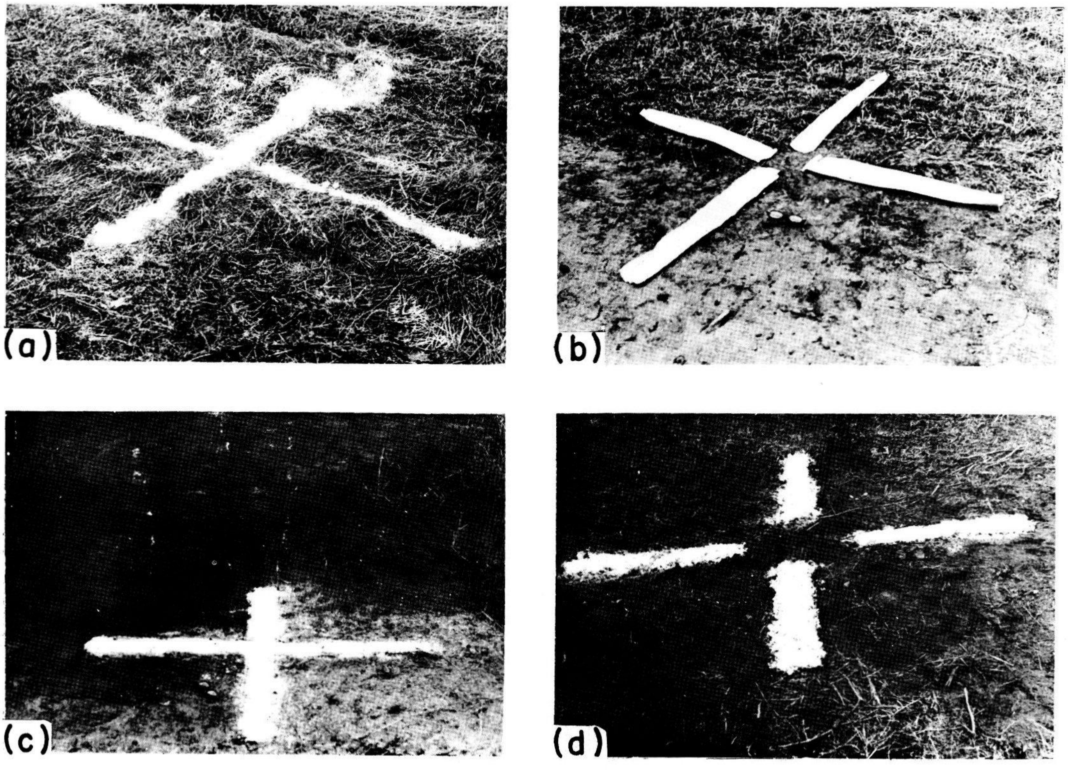


Figure 7. Some targets used for placement on markers of control points in Kansas research projects to determine a good material and proper procedure for setting targets. (a) Very rough X limed target marker; target used with good success; open cross, however, better target. (b) Typical target made of canvas, using four strips. Two strips may be used, however, by darkening center portion with dirt or paint. (c) Typical closed cross constructed of lime by using care in placing lime to general size and shape suggested for photography taken from a flight height 1,500 ft. (d) Typical open center cross made of lime and having same characteristics as closed cross. This cross seems to have best characteristics for pass points at which elevation is measured for leveling stereoscopic models.

Compilation Section

Compilation is accomplished with four 5:1 projection ratio Kelsh stereoscopic plotters. Two of the plotters are the three-projector type. Eight plotter operators are utilized by the section. This insures full plotter usage, provides the ability to send a plotter operator to the field to supervise a survey, and allows for leave time, normal setup procedures, note checking, and data gathering which precedes and follows the working of a stereoscopic model on the plotter.

Most design data comes from the plotter in the form of a topographic strip map, profile and cross-sections. The cross-sections and profile data are recorded by use of recording machines. This information is later placed into note form, reproduced directly by the key punch section onto cards, or plotted, as the project demands. A cross-section measuring and recording device is on order which will directly produce the information in card form for electronic processing.

Many topographic maps are produced by the section for purposes such as highway centerline study and drainage structure location. The map scale varies from 40 to 100 ft to 1 in. The most common scale is 50 ft to 1 in., with a 2-ft contour interval. Many routes are mapped or profiled for the purpose of estimating quantities.

The alignment problem in Kansas, with its many existing roads, is not a problem of quantities as much as one of existing topographic features. Urban areas are often compiled as planimetric maps with contours being measured and delineated only in critical areas. Before the addition of the second two stereoscopic plotters, the section was operating on a split shift basis using the plotters 12 hr a day. The section has had the Kelsh instruments in operation continuously, except for two short periods when lack of ground control or photography delayed their utilization.

The Compilation Section, after three trial projects, is also measuring and recording the cross-sections from which payment quantities are computed. Many projects are closed with the contractor accepting the design quantities for payment. In the cases where this acceptance is not forthcoming, cross-sections for computation of pay quantities are measured photogrammetrically. The Photogrammetric Section has been used for this purpose on five such projects. The reaction to such use cannot be determined at this time, but with the continuance of this procedure, all of the difficulties should be eliminated and this will be a regular function of the Section on many projects.

Because of the close control of the designer assigned to the project and the section there has been no need during the past year to reset stereoscopic models in the precision instruments. The problems of centerline alternatives have been resolved early and although the section is often called on to produce data for alternatives, only one alternative highway route area is mapped in detail.

General

There has been little use made of the State plane coordinate system by the Section, probably because application of the system is not required by law in Kansas. Research in the use of strip cameras has been made. Color photography has been tried on several projects and further research in this area is expected. Much use of photographic enlargements for public hearings and in the condemnation cases of rights-of-way has been made. The use of models has been studied. It is hoped use of the State plane coordinate system will become an important part of all highway surveying and plans in the future.

PHOTOGRAMMETRY AND HIGHWAYS

James M. Carigan
Kentucky Department of Highways

The Kentucky Department of Highways has utilized photogrammetry since 1954. At that time, a small photogrammetric unit was established, patterned after an experimental photogrammetric section in the Ohio Department of Highways.

Until 1957 the Photogrammetric Section made surveys of rural secondary highway routes and bridge sites. These particular surveys were not accomplished as economically by photogrammetric methods as they might have been by conventional methods on the ground because the available equipment was, in many cases, antiquated and impossible to maintain properly. Aerial photography was available only through contract with commercial photographers. The unwieldy contract procedure required that a program be prepared preferably 2 yr before the design phase of each highway location was to start.

In July 1957, following passage of the Federal-Aid Highway Act of 1956, the department acquired an aircraft, aerial camera, pilots, and photographers, and commenced an expanded aerial photographic program. The staff of 14 employees was enlarged to 50, three Kelsh double-projection stereoscopic plotters were added to make a total of five; four more darkrooms were added to the original one; a 24-in. copy camera was replaced by a 41-in. one; a precision, distortion-free aerial camera was acquired; a personnel training program was instituted; a part-time field survey party was expanded to two full-time parties, and all equipment was modernized.

All planning for this launching was based on glowing predictions and advance reports that proclaimed vast money savings and tremendous time reductions to be gained by the use of photogrammetry in highway surveying and design. Unfortunately, the reporting was done by men who assumed conventional design procedures were to be scrapped or revised to the extent photogrammetry could readily be used to gather all design data, without any of the usual survey methods being employed. This was not the case. It soon became apparent design procedures were not to be altered appreciably. Photogrammetry could not be used without a complete conventional field survey of the exact roadway centerline, precise field measurement of each highway location profile, and physical soil examination and rock soundings on staked centerline stations.

Under these requirements, it was soon learned that any benefit to accrue from photogrammetry could come only through measuring of the ground across the highway route corridor and compiling cultural details by photogrammetric methods. The advantage of photogrammetry in these operations is substantial, but is somewhat offset by the necessary ground surveying.

One definite advantage with the photogrammetric method is the greatly increased amount of information of all types available with no increase in cost. As a result, the roadway design engineers are given much more pertinent and accurate data on which to base their design. The end product must necessarily be better design and reduced construction costs, the latter being probably the largest single benefit.

During the period from July 1957 to March 1961, the roadway design was done from photogrammetrically made surveys accomplished by the Kentucky Department of Highways Aerial Engineering Section on a wide front, encompassing surveys throughout the whole State. Results of these surveys were quite varied: some were excellent, some were ordinary, and some were indeterminate.

Although costs of engineering work based on photogrammetrically made surveys were rather indeterminate as compared to costs based on surveys made by conventional methods on the ground, they were quite low in comparison with the typical engineering consultant fee prevalent during this period. Considering only limited-access highways on Interstate routes, the Aerial Engineering Section located, surveyed, and completed design on 51.7 mi of 4-lane, divided, limited-access highways. Also completed were 11 interchanges. This work includes 11.0 mi of Fayette County, I-64, 3.2 mi of Clark County, I-64; 5.0 mi of Clark County, I-64; 13.7 mi of Fayette County Lexington Relief Route; 3.3 mi of Jefferson County, I-71; 3.5 mi of Carter County, I-64; and 12.0 mi of Daviess County, US 431. The completely designed interchanges were on the

Lexington Relief Route intersecting US 421, Old Frankfort Pike, US 60, US 68, US 27, Tates Creek Pike, and US 25. Other completely designed interchanges were on I-64 in Fayette and Clark Counties, including the intersections at US 227, Van Meter Road, and Haley Road. Combined interchanges and road mileage designed represent an estimated construction cost of approximately $40,000,000. A reasonable consulting engineer's fee for this work would be $1,600,000. Figuring liberally, the survey and design cost incurred by the Aerial Engineering Section would not exceed $700,000. This logic should illustrate the Kentucky Department of Highways benefited financially to the extent of nearly a million dollars in design alone. This work was carried out entirely by the Aerial Engineering Section with the other Kentucky Department of Highways design offices functioning undisturbed and without interference.

The construction savings can only be estimated and will never be absolutely known. An illustration, however, can be made of the portion of the Fayette County Lexington Relief Route, from US 421 to US 60, approximately 2.5 mi with an interchange proposed at each end. This road was surveyed, designed, and construction cost estimates were prepared for the entire project. A revision was requested for an interchange to be added at Old Frankfort Pike. Using aerial surveys, it was not necessary to return to the field, except for staking and making soundings of the proposed additional interchange ramps. The field work required only 2 days. The entire length of the grade was adjusted by a combination of photogrammetry and electronic computation. The centerline gradients were established, yardage computed, and grades adjusted to secure the most efficient distribution of material. The newly estimated construction cost (including complete cost of the additional interchange) was below the original construction cost estimate.

Another striking example of assumed construction savings occurred on the Fayette-Clark I-64 from Hume Road in Lexington, eastward to Van Meter Road in Winchester. On the preliminary engineering report, this approximately 16-mi section contained, by estimate, 2,600,000 cu yd of earthwork excavation, whereas after combined photogrammetric-electronic grade adjustments, the yardage estimated on design was 1,208,418 cu yd. This represented construction savings of approximately $900,000.

From July 1957 to March 1961, the Aerial Engineering Section completed the following projects: US 31W in Warren County, 10 mi field survey completed, 15 mi staked in field and photographed in Warren and Edmonson Counties; US 227 in Clark and Bourbon Counties, 16 mi centerline staked in field and aerial photography taken and controlled in field; US 68 in Todd, Christian, and Logan Counties, 25 mi centerline staked in field, aerial photography taken and controlled, and design quantities obtained; and Ky. Rt. 15 in Perry and Letcher Counties, 7.5 mi of aerial photography taken, controlled, and design data obtained. Altogether these projects total approximately 70 mi of completed photogrammetric and field surveys for roadway design. The total cost of salaries and expenses on these projects was less than $75,000 or approximately $1,000/mi, which also includes preliminary evaluation of route alternatives in nearly all cases.

During this same 3-yr period, the section also produced 126 mi of detailed topographic maps of topography strips along major Interstate and Federal-aid primary routes for advance route determination purposes. Total survey costs were less than $500/mi for rural and $800/mi for highly congested urban mapping. All of this mapping has been accurately and promptly completed, often at a cost of less than $200 per highway mile. Miscellaneous detail topographic mapping was also completed, including three lake site maps totaling 4,158 acres, 11 roadside park sites and 19 highway interchange sites.

The Aerial Engineering Section exposed 80 rolls of aerial film negatives, comprising 15,200 individual negatives. More than 30,000 contact prints and 16,000 photographic enlargements have been produced and distributed, principally to the Divisions of Design, Right-of-Way, and Planning.

The entire length of the proposed Kentucky Interstate System has been photographed (more than 800 linear miles, considering revisions), and more than 1,000 linear miles of Federal-aid primary and secondary routes. The Aerial Engineering Section has produced and delivered more than 10,000 copies of existing maps, photographs, and engineering drawings using the 41-in. overhead copy camera. This copy work has been distributed to all divisions of the Kentucky Department of Highways, and also to other departments of Kentucky governmental agencies.

Concurrent with these events, the Aerial Engineering Section has carried on an accelerated experimentation program to develop and refine photographic and photogrammetric techniques applicable to the improving of highway engineering methods. Some of the more important applications of photogrammetry are:

1. On current aerial photography, the Right-of-Way Division has been able to identify pertinent data properly and easily in order to establish quickly the comparative value of land parcels. Use of photographs has also been made for liaison between the Department of Highways and the individual property owners for improving public relations and for speeding land acquisition. As an aid to the Department of Highways in court suits, use of aerial vertical and/or oblique photographs has often been instrumental in securing swift and reasonable judgments.

2. Aerial photography has proved to be the most satisfactory means of displaying proposed highway routes to the general public.

3. Highway system planning operations and highway route location have been greatly facilitated by the use of current aerial photography. Proper use of this photography enables the planner to see type and intensity of both urban and rural land development. Also, the photographs, fully used photogrammetrically and by photographic interpretation, provide pertinent dimensions and qualitative data about the land use, topography, soils, ground conditions, and drainage for determining the best highway routes.

4. Photographs are useful in correlation of traffic origin and destination studies. Traffic studies and their probable solutions are more quickly accomplished through the use of currently taken aerial photographs. Studies can be made of traffic congestion and traffic bottlenecks to determine the type, nature, and time of peak traffic in areas of known congestion. Also, aerial photography properly used will reveal the deterioration of roadways, paint striping, etc.

5. Road location and design operations make many applications of photographic materials and procedures practicable, beginning with small-scale strip mosaics of aerial photographs (scale, 1,000 ft to 1 in.) for reconnaissance surveying and highway route determination, and continuing through the preliminary survey and design procedure to the preparation of detailed construction plans, often supplemented by large-scale photographic mosaics assembled from large-scale aerial photographs. These mosaics may reveal even individual clumps of grass, giving highway design engineers more complete information than any other feasible method.

6. Aerial photography, both vertical and oblique, has been used advantageously in recording and displaying roadway construction progress and as a check on construction techniques. Photography can be used also to record and display construction failures, earthslides, embankment failures, etc.

7. The use of photogrammetry for measuring cross-sections of constructed highways to determine earthwork pay quantities has been found to be practicable and probably desirable, particularly if cross-section measurements of the original ground have been punched into cards for use in the electronic computer. The constructed highway cross-sections are measured with the Kelsh stereoscopic plotter and an electronic digitizer to automatically punch the measured dimensions into electronic computer data cards. This procedure certainly saves manpower, time, and money for the Highway Department, and should greatly expedite payments to construction contractors.

The measurement of constructed highway cross-sections is a part of highway surveys more peculiarly adaptable to photogrammetry than any other type of highway surveying. Photography for photogrammetrically measuring construction quantities can be flown and taken at any time of the year and under varying weather conditions, thus there is unlimited possiblity for mass production.

8. Aerial photography can show areas of proposed construction in a before-and-after sequence by artistic drawing directly on oblique photographs. This permits demonstration of proposed construction to interested groups before final decisions are made.

There are many other aerial photographic uses and techniques which may be realized by use of only a small amount of thought and imagination. It is certain that as photographic techniques, films, cameras, and knowledge increase, the uses of photogrammetry will increase.

USE OF PHOTOGRAMMETRY IN MONTANA

After the advent of the Interstate System in 1956, a requirement of which was an estimation of the cost of constructing the highway in each State, a State-wide aerial mapping contract was entered into by the Montana State Highway Commission for topographic mapping of the entire system. A scale of 200 ft to 1 in. with a contour interval of 5 ft was chosen for the general mapping, with some sections being mapped at a scale of 100 ft to 1 in. with a 2-ft contour interval.

On completion of the contract and after use of the mapping for several months, the great value of photogrammetric products became evident to the engineering personnel and, as a result, it was decided to enter into the photogrammetric field. A small economical print-type stereoscopic plotter was purchased, along with mirror stereoscopes and parallax bars.

Because of Montana's inclement weather and the lack of private aerial photography companies in the State, it was decided in 1957 to purchase a Cessna 180 with aerial camera. Related darkroom equipment was also purchased. Because of continued utilization of photogrammetric products and the increased work load two Kelsh stereoscopic plotters were purchased by 1959. More accurate design mapping was the constant demand of design engineers, including structural designers.

In keeping with these demands, a LogEtronic automatic dodging printer was purchased and a specialist was trained in ground control. The regular field survey crews within the State are used along with the specialist who selects the finite image points, sets the targets, and trains other personnel in these techniques. By 1960 the original camera was replaced by a Wild RC-8 aerial camera.

The Photogrammetry Section is assigned to the Interstate Department because 99 percent of its work is performed on Interstate highways. Of the aforementioned personnel, two are supervisory, one is assigned to the field, two are part-time and also do work for other departments, and four are photogrammetric instrument operators and draftsmen.

From the fall of 1958 to 1961 more than 200 sq mi of reconnaissance topographic mapping was accomplished. More than 80 percent of this mapping is done at the scale of 200 ft to 1 in., with a 5-ft contour interval, and the remainder is done at the scale of 400 ft to 1 in., with a 10-ft interval. This work also includes approximately 50 sq mi of design mapping at scales of 50 ft and 100 ft to 1 in., with a 1- and 2-ft contour intervals, respectively. Another 100 sq mi of mapping is under way. Thus far no cross-sections have been measured photogrammetrically, other than extension of field measured cross-sections.

Other specialized work completed includes the assembly of an uncontrolled mosaic of every city, town, and hamlet in the State. These mosaics are to be incorporated into a book to complement the City Plat Book already produced by the State Highway Commission. The feasibility of furnishing the construction department monthly aerial photography of the highway construction projects to verify monthly progress reports and payments is being studied.

The Right-of-Way Department is furnished enlarged aerial photographs at a scale of 200 ft to 1 in. or larger of all Interstate projects to facilitate negotiations. This photography is acquired as near to the time of negotiation and purchase as possible to insure obtaining the most up-to-date information possible.

Research is being done on the utilization of various methods of ground control when surveying in very rugged mountainous topography for different mapping scales. This includes the use of electronic distance measuring devices alone and in conjunction with field survey crews utilizing conventional methods.

Many aerial photography, photographic mosaic, and topographic map displays are made for the legal staff and have proven invaluable in condemnation suits. Such displays are also made for the Public Information Section.

CURRENT PHOTOGRAMMETRIC PRACTICES IN VIRGINIA

Fred B. Bales
Virginia Department of Highways

Before photogrammetry can be utilized to its fullest extent, the user must recognize its limitations. Photogrammetry is not the highway engineering cure-all prophesied by so many during the past few years. It must be employed with discretion and with close quality control.

In Virginia, only equipment and materials known to consistently provide high quality results are used. Photography, for instance, is taken using only a stable base aerial film and an aerial camera with a distortion-free lens. Diapositives are printed only on glass plates ¼ in. thick. Map manuscripts are compiled using only a stable base drafting film on which control points are plotted by means of a precision coordinatograph.

Ground control for mapping by aerial methods is established with Tellurometers for distance measurement and Wild T-2 theodolites for angular measurement. Two masters and two remotes of the early model MRA/1 Tellurometer and the later addition of two units of the MRA/2 model provide three complete distance measuring systems.

For quality control, a test profile is measured routinely on the ground during establishment of ground control for each stereoscopic model from which a map is to be compiled. The profile data, however, are withheld from the stereoscopic instrument operator until after each stereoscopic model has been used in compiling the maps and making other essential measurements. An independent check is then made by a supervisor to determine completeness of planimetric detail and accuracy of the contour delineations or cross-section measurements. This check is made before the setup of each successive stereoscopic model is removed from the photogrammetric instrument.

The actual utilization of photogrammetric equipment for highway engineering in the State can be placed in two distinct areas: (a) route location stages, and (b) accumulation of survey data for use in highway design. In the route location stages, topographic mapping is accomplished at a scale of 200 ft to 1 in. with a 5-ft contour interval. For highway design, the maps are compiled at a scale of 50 ft to 1 in. with a 2-ft contour interval or cross-sections are measured photogrammetrically using stereoscopic models of the same scale.

Aerial photography is taken using a State-owned Aero Commander twin engine aircraft with a Wild RC-8 aerial camera. Both pilot and photographer are former survey party personnel who have other office duties within the highway location section when not actually engaged in flying.

A complete photographic laboratory is maintained for processing the exposed aerial film and printing photographs on paper and on glass as needed. Contact printing is accomplished through the use of an automatic electronic dodging printer and enlargements are made utilizing a Zeiss SEG-V Rectifier-Enlarger. Photographic mosaics are copied using an overhead-type Robertson copy camera. This camera is used for all departmental copy work, including road and bridge plans, maps, and sketches, and further doubles as a photographic enlarger.

All ground control for the route location topographic mapping (scale of 200 ft to 1 in. with a 5-ft contour interval) is accomplished by three survey parties equipped with Tellurometers, Wild T-2 theodolites, and Zeiss automatic self-leveling levels. Horizontal control for all such mapping is based on the Virginia State plane coordinate system and vertical control on sea level datum. All traverses for ground control are computed and adjusted by electronic computer. Because the photographic image of each horizontal control point is usually off the main traverse, the traverse program was written to include computation and adjustment of the supplemental measurements to these points.

Compilation of the topographic detail is accomplished utilizing five Kelsh stereoscopic plotting instruments. The compilation is made on an emulsion coated stable base drafting film in pencil after which the map is completed using scribe techniques. Each scribe sheet actually serves as a photographic negative from which copies of each completed map are produced photographically on stable base Cronaflex material. The only inking involved is in labeling the elevation of contours and identifying other map features. During the last fiscal year, approximately 173 sq mi of mapping were completed in addition to the other larger scale contour delineation and cross-section measuring accomplished by the mapping unit.

The topographic mapping serves as the basis for subsequent route location and as a means for reporting route alternatives and making recommendations. This phase is accomplished well in advance of design and subsequent location survey staking of the highway on the ground.

After a highway survey and design project is advanced to the location survey stage where the centerline is to be staked on the ground, a combination of techniques is employed involving both photogrammetric and conventional field surveying practices. Where ground cover is so tall and dense that accurate measurements cannot be made by use of aerial photography, ground survey methods are used exclusively. On some projects only the cross-sections are measured and contours for interchanges are delineated by photogrammetric methods. On other projects all planimetric detail is also delineated (generally referred to as topography). On some projects a topographic map is compiled of the entire project, measuring and delineating the contours on a 2-ft interval. More recently the photogrammetric methods have been confined to measurement of cross-sections using a Benson-Lehner Terrain Data Translator coupled to a Kelsh stereoscopic plotter. The cross-section data in digital form are punched directly into cards.

The preferred approach in making this type of survey is to first establish a survey baseline on the ground, tie the centerline into the State plane coordinate system and then measure on the ground the profile of this baseline. The baseline is then targeted at 500-ft intervals. An attempt is made to target the centerline or baseline for all location-type surveys involving the photogrammetric measurement of cross-sections. Where there are likely to be few natural ground image points, such as in wooded areas, cultivated fields and meadows, additional targets are placed near the outer limits of the area to be photographed for use as stereoscopic model leveling points.

Targets are printed in the form of a cross on 45-in. squares of white muslin cloth and are fastened at the corners by gutter spikes 7 in. long (Fig. 8). These printed targets cost approximately $0.30 each and are extremely easy to transport and place on the ground. In wooded areas where the targets are somewhat difficult to identify, two strips of white muslin cloth, 9 in. wide and 10 ft long, are first placed over the points in the form of a cross and the small target is placed in the center to provide contrast.

After all targets are placed on the ground and the photography mission is completed, photographic prints are furnished the ground control survey parties for use in identifying all visible targets and in establishing vertical control along or near the outer limits of the photography. Where targets have been destroyed by animals, cattle, deer, and the like, sharply defined natural images are selected to serve as control points.

The plane coordinate computed centerline or baseline is plotted on stable base drafting film using the Aristo coordinatograph and the targeted horizontal control points. The electronic computer traverse program automatically computes the plane coordinates in increments of 500 ft, greatly facilitating the plotting of centerlines on the manuscript, particularly where curves are involved.

The actual photogrammetric instrumentation work is accomplished by means of an electronic digital measuring and recording system. The Terrain Data Translator

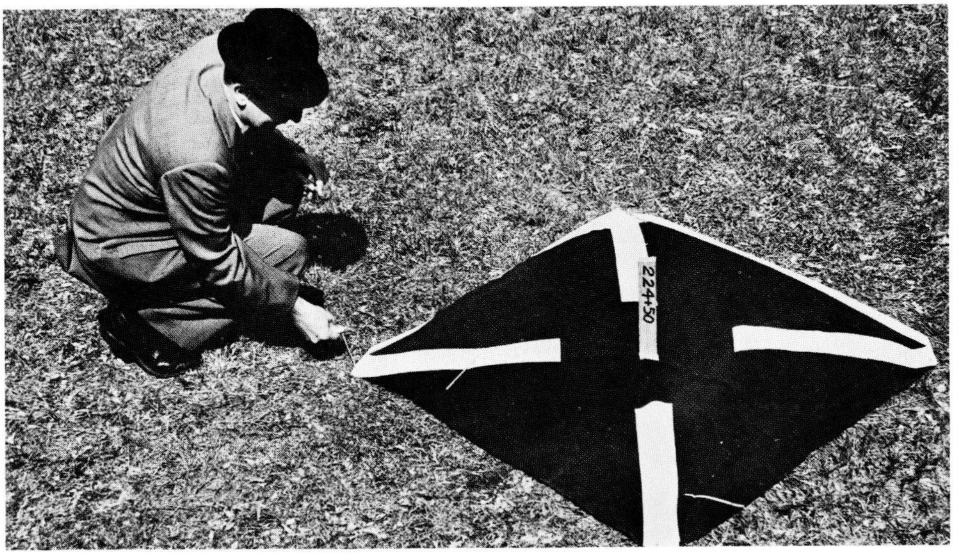


Figure 8. Target for aerial surveys.

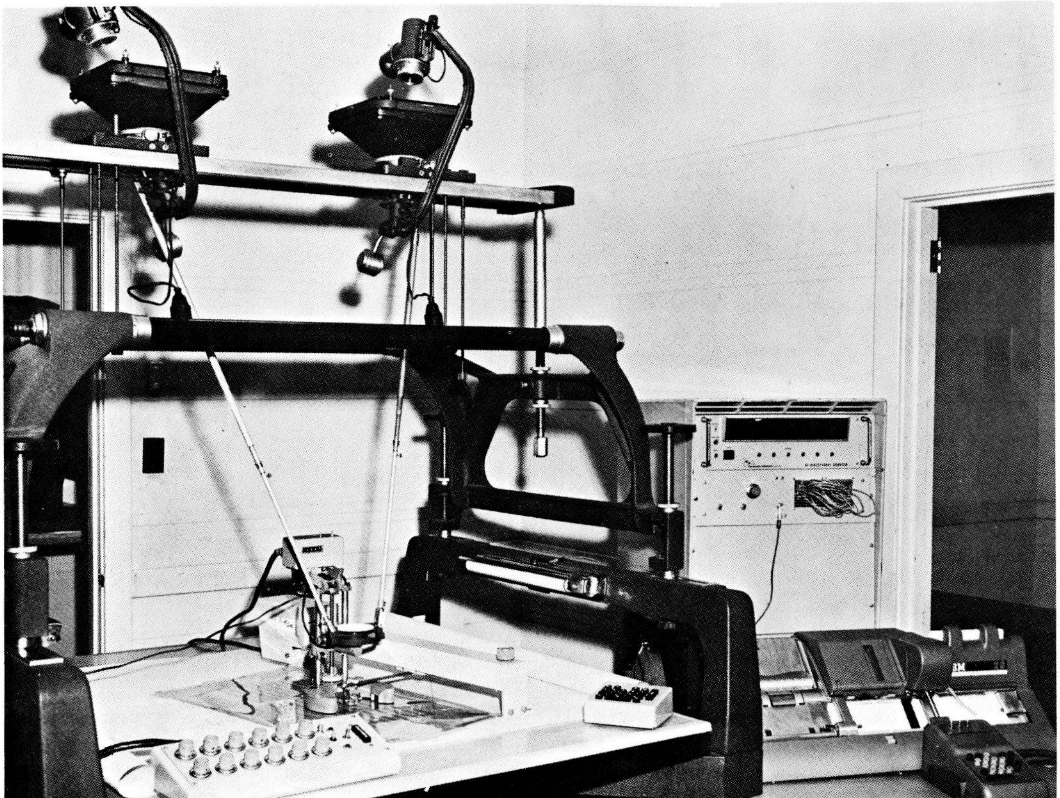


Figure 9. Benson-Lehner Terrain Data Translator.

(Fig. 9) being used for this work is the transistorized or solid state model with the Nixie Tube display for horizontal distance. The photogrammetric instrument operator by means of a horizontal scaler makes a cross-section point measurement at each 20-ft increment plus all breaks in the ground line. To maintain the 20-ft increment, the operator needs only to glance at a transparent overlay consisting of several parallel 24-in. long scales and used for horizontal alignment of the scaler.

As originally designed, the horizontal scaler had to be moved and re-aligned at right angles to the survey line for each cross-section measured. The arm that attaches to the chuck of the Kelsh tracing table has been lengthened and small holes drilled on centers 1 in. apart. The tracing table can now be moved from hole to hole, each of which is equal to the ground distance of 50 ft at stereoscopic model scale and provides seven cross-section positioning lines for tangents without moving the horizontal scaler.

Improvements have been made in the method by which digital data are transferred to punched cards. Star wheels were added to the key punch program card to (a) automatically enter the fixed data, (b) advance the card numbering relay at the end of each card, and (c) light a lamp on the control unit to indicate that the digital data are being entered in the proper position in the card. In addition, a switch was added to the TDT control unit to record the measured centerline elevation from the control unit rather than from the Kelsh tracing table. This switch also zeros the horizontal distance on the TDT display and transfers the information to the IBM card when crossing centerline. After the station number and centerline elevation are set into the control unit, the operator has only to concentrate on making the successive point measurements for each cross-section, regardless of the number of cards for each cross-sectioning station. On completion of the measurements for a cross-section, the instrument operator sets station number and centerline elevation for the next cross-section and zeros his card counter. Then he rejects the last card containing the previous cross-section data and the new fixed data are entered automatically.

Once the stereoscopic model is set up and the TDT coupled to the tracing table, instrument operators have been measuring around 500 cross-section points per hour. Under ideal conditions, however, where there is very little ground cover, they can measure about 700 cross-section points per hour. Before the instrument modifications were made, the instrument operators were averaging around 250 to 300 points per hour, 50 to 100 points per hour more than when the measurements were made and recorded entirely by manual methods. These rates do not, however, reflect the time required for making each stereoscopic model setup.

The TDT with the special modifications is capable of re-cycling at such a rate as to permit visual observation and automatic recording of the measurements of 1,700 points per hour, but this is allowing no time for change of station number and elevation or for re-alignment of the horizontal scaler at right angles to the centerline.

Perhaps another factor contributing to the increased productivity of the electronic system is the ability of each photogrammetric instrument operator to hold his stereoscopic vision, particularly in wooded areas and where the ground slopes are steep. With the electronic system, the instrument operator can keep his eyes constantly on the stereoscopic model, but when using manual methods he was constantly glancing away from the stereoscopic model to view and mark the tracing table distance from centerline and would momentarily lose his vision of the streoscopic model.

The TDT can be used to the best advantage with two separate Kelsh stereoscopic plotters. The digital measurement and recording of cross-section data are accomplished from one photogrammetric instrument while a stereoscopic model is being set up in the other. On completion of measurements and recording with the first instrument, the TDT is coupled to the next instrument.

Areas where heavy foliage obscures the ground still require conventional ground survey procedures and later punching of the measurements into cards by manual methods.

After all cross-section measurements are punched for each location survey project, they are sent through the IBM checking program. This checking program verifies the centerline elevation from card to card, checks for vertical differences of 50 ft or greater between adjacent cross-sections at the centerline point and also indicates where no centerline point is recorded. It further indicates where horizontal distances between adjacent cross-sections are not decreasing from left to center or increasing from center to the right and when there is a vertical difference of 20 ft or more between adjacent points on each cross-section. It also indicates when the photogrammetrically or otherwise measured elevation at the center of the cross-section does not agree with the elevation measured by spirit levels for centerline stationing points.

The designers seem to welcome projects where the cross-sections have been measured by photogrammetric methods. When they encounter unusual problems in design and need additional information, cross-sections or contours can usually be furnished from the stereoscopic models in a matter of hours, in contrast to the several days or weeks required to obtain additional survey information from the field when surveys are made by conventional methods on the ground.

Photographic mosaics and enlargements of aerial photographs are utilized in most phases of route location, traffic analysis, geologic and soil analysis, preparation of right-of-way cost estimates, and drainage studies.

When highway projects are advanced to the design stage, the first thing the designers generally request is a set of aerial photographs. Photographic enlargements are generally requested during the early stages of design. After the highway construction plans are advanced to the procurement of rights-of-way, photographic enlargements are furnished for appraisal work and are frequently furnished for use in condemnation cases.

It is felt that photographic mosaics prepared by orthophotographic methods will have a very definite place in the highway engineering program. Orthophotographs will provide a means whereby the aerial photography images can be accurately portrayed on highway plan sheets, thus greatly enhancing the usefulness of photography in all phases of highway engineering. An instrument called the orthophotoscope has been developed by the U. S. Geological Survey which compensates for the image displacement due to relief height. It provides a photographic map from which distances can be accurately scaled between features and eliminates the need for much symbolization to indicate land uses, topographic features, vegetation, etc.

Photogrammetry and photogrammetry united with electronics for measuring and digital recording of specific measurements have provided the means for greatly increasing engineering productivity in Virginia.

Part II

Technical Excerpts from Committee Meeting Discussions

(Committee on Photogrammetry and Aerial Surveys)

11TH MEETING, JANUARY 8 AND 10, 1962
(Washington, D. C.)

1. D. J. Olinger resigned from his position as Committee Chairman, because his official duties in the Wyoming Highway Department had been changed. William T. Pryor became Acting Chairman.

2. Mr. Pryor remarked many reports available for reference use in establishing aerial survey units or in contracting for aerial survey services do not contain such specifics as why certain scales are used for mapping and what the benefits are in using a particular scale. This committee by appropriate design and reporting summary results of a questionnaire can fill such a void. For lack of such a report nearly 10 yr ago, for example, engineers of Georgia chose to travel personally to other States to learn about their problems and to obtain details regarding the manner in which their problems are solved through having an aerial surveys unit in their highway development. There is a definite need for a questionnaire so experiences can be shared by everyone. (See "Results of 1962 Questionnaire on Use of Aerial Surveys," in Highway Res. News 6, June 1962.)

3. John O. Eichler supplied a listing of selected references on use of aerial photography for analyzing highway traffic movement. There are no colleges stressing photogrammetry and aerial surveys, as specifically practiced in highway engineering, and most of the photogrammetric research is not done for highway purposes. Highway departments or the National Science Foundation should undertake and finance research projects to improve aerial surveys and photogrammetric practices in the highway field. One significant need now is research in analytical triangulation.

a. Mr. Pryor stated a stereocomparator would be desirable for accomplishing analytical triangulation research. Federal agencies have problems in procuring expensive equipment to get research under way. Each committee member should continue to stress State and Federal cooperative research. Highway Planning Survey funds can be used cooperatively in the photogrammetric field.

In relation to research, the problem for some is the need for new developments or to improve techniques and procedures while the engineering work is being done. Some progress has been made through such practice. Sometimes the project type of development and improvement is successful in getting funds to defray instrument costs which can be charged to the engineering projects instead of to research alone.

b. Marshall S. Wright, Jr., of Lockwood, Kessler and Bartlett Co., Syosset, L. I., N. Y., a consultant engineering firm remarked he did not feel a stereocomparator is essential to mathematical research in photogrammetric applications within the highway engineering field. Any optical-train photogrammetric instrument could be used to measure stereoscopic model coordinates.

c. George P. Katibah and Professor Eichler concurred that, for one research project only, rental would be more economical than purchase of a stereocomparator.

d. Mr. Pryor mentioned group purchase of one stereocomparator for continual research and for specific project engineering work would permit separate research and engineering projects to share the cost on a rental basis. No one project would be burdened with the total cost.

4. Mr. Pryor called for a review of topics in which needs are most urgent for performance of research.

a. Olin W. Mintzer requested information concerning legal acceptance of right-of-way descriptions prepared from photogrammetrically made measurements.

b. Mr. Pryor mentioned General Land Office regulations, unless modified, require points marking property corners and lines to be occupied and measurements made on the ground physically (to and between the points) for a cadastral survey to be legally recognized. A campaign would have to be conducted to get photogrammetric measurements accepted legally.

c. E. D. Hovde, Supervising Highway Engineer, California Division of Highways, said that if errors are made in ground surveys, courts will not challenge ground survey methods but would challenge photogrammetry as a method of making measurements should errors be made in its use. Courts sometimes assume there are limitations to photogrammetry. Consequently, it is satisfactory to use photogrammetry only if users are willing to pay for the extra land areas resulting from errors, when they occur, in the photogrammetric measurement of boundaries. The consequences of permissible error limit in photogrammetric work cannot be avoided. Blunders and systematic errors should be eliminated.

d. Professor Mintzer proposed a study be made to determine where photogrammetric methods would be acceptable in the courts.

e. Mr. Katibah stated random errors present in ground surveys are, from a practical point of view, completely eliminated by precision use of aerial photographs in appropriate stereoscopic instrumentation procedures.

f. Mr. Hovde thought the position of property corners and lines can be measured by photogrammetry as well as by ground surveys, although ground surveys are more likely to contain larger random errors.

g. Robert D. Miles mentioned a project done by photogrammetric and ground survey methods. The accuracies in position measurement of fixed property corners were within 0.2 ft by photogrammetric methods.

h. Mr. Hovde said if photogrammetric methods can be devised to assure measurement accuracies commensurate with those attained by ground survey methods, they would be acceptable. Research along such lines would be justified.

i. Mr. Pryor said millions of dollars have been spent, and will yet be spent, to purchase rights-of-way, so the committee should promote research in cadastral surveying by photogrammetric methods.

j. Mr. Katibah suggested several States could contribute both funds and effort to one research project.

k. Professor Eichler mentioned nothing is ever fully completed in research, as it is a door-opening process, which leads to need for its continuation not termination.

l. Uses by the States of a plane coordinate system was discussed. Ohio is trying to get all property surveys made for procurement of highway rights-of-way to originate and close on geodetic markers of the State plane coordinate system.

On request, the U. S. Bureau of Public Roads has computed a combined adjustment factor for several of the southern and midwest States which establishes another datum for the plane coordinate system parallel to the datum initially established by the U. S. Coast and Geodetic Survey. By this procedure, distances determined from the plane coordinates of survey points and map features will agree within practical limits, without need for any adjustment, with distances measured on the ground between the same survey points and map features. This adjustment is applied directly to all basic control obtained from the U. S. Coast and Geodetic Survey for each plane coordinate zone in the State. The basic and supplemental control surveys for each highway survey project are then made and mapping accomplished based on the new plane coordinate datum. In this way, map and ground distances are in sufficient agreement to preclude any need for individual adjustment in making transfer of designed alignment and rights-of-way dimensions from the highway construction plans to the ground, and vice versa. In this manner, rights-of-way corners and points on rights-of-way lines are all related to the plane coordinate system and are as position accurate as the measurements made in the basic control surveys for each highway survey project.

m. Professor Mintzer remarked that when property boundaries have been previously established by ground surveys and photogrammetric methods are introduced to recover the old boundaries, some means must be devised to convince the courts that photogrammetric methods are sufficiently accurate and, therefore, should have legal acceptance.

n. Robert L. Lewis, Supervising Designing Engineer, Texas Highway Department, said Texas successfully utilizes photogrammetry for land (cadastral) surveys. Only when court condemnation is required to procure specific parcels of land, and photogrammetrically made measurements are challenged, are the cadastral measurements made by surveys on the ground.

o. Glenn Aschutz suggested there is need for research in the general field of photographic interpretation, especially soil types and land forms in a specific area.

p. Harold T. Rib reminded the committee a research problem statement had been written on "Classification of Materials During Preliminary Survey State by Photographic Interpreation."

5. Mr. Pryor invited highway departments to begin using the remote baseline method of making supplemental control surveys for measuring the elevation of vertical control points and position of horizontal control points of both photographic target and natural image-type points. (See "Remote Base Line Method of Measuring Horizontal and Vertical Control," by W. T. Pryor, in HRB Bull. 354, 1962, pp. 32-50.)

a. Fred B. Bales said Virginia was using the Tellurometer to accomplish this type of work, but he felt it would be difficult in areas of heavy foliage to make the essential angle measuring instrument sightings on the extremities of the remote baseline.

b. Dwight E. Winsor stated the remote baseline method could be put into effect by anyone as written. The method is fast and accurate if used correctly for making supplemental control surveys and for finding errors in survey project traverses that fail to close on basic control with sufficient accuracy. The method definitely has a practical application, especially where chaining (tape measuring) is difficult because of character of topography or of interferences by traffic.

6. Charles E. McNoldy said construction contractors in Pennsylvania have not accepted earthwork volumes obtained from digital terrain models. He solicited information regarding the experience of others in getting acceptance of digital model data and other photogrammetrically measured dimensional data by highway design engineers.

a. Mr. Pryor stated it had been his experience highway engineers will use and accept procedures if they have no alternatives, and construction contractors usually accept the measurements highway engineers make and have faith in.

b. Mr. Lewis described Texas' experience and acceptance of electronically computed plane coordinates, and distances and angle measurement data. The Texans were pleased with the amount of information made available. Highway people, like others, are reluctant to accept a new method. but once it is proven, they become enthusiastic about it.

7. Mr. Katibah said he and other engineers in California felt a recent report presented at an AASHO meeting may create improper impressions within highway departments because fabulous gains in automation of photogrammetric instruments were claimed.

Mr. Pryor reminded the Photogrammetry and Aerial Surveys Committee that its conservative policies are proper. It is best to plan and accomplish a complete study and report facts rather than to be so optimistic that objectives are reported in such a way that they may be accepted as attained goals.

a. Mr. Anschutz said the State highway engineer of Kansas had received the AASHO communication mentioned, but that Kansas engineers did not get as alarmed as the engineers in California about the reports.

b. Mr. Pryor outlined the principles on which various automatic stereoscopic plotting instruments are based and indicated some of the difficulties being encountered with these instruments: the instruments are not capable of distinguishing accurately the ground surface among trees and buildings, and are not yet operational wherever ground slopes were irregularly rugged or uniformly steep. Automation of photogrammetric instruments is desirable, but such problems must be solved and sufficient operational reliability and accuracy achieved before the techniques can be recommended for displacement of current photogrammetric instrumentaion.

c. Mr. Katibah stated that, whereas automatic plotting instruments are desirable, to his knowledge such instruments are being developed for military and not for highway applications. He knew of no report of research findings on whether or not the instruments would work.

d. Mr. Anschutz said that practical utilization in Kansas of automatic photogrammetric instruments is perhaps ten or more years away. Moreover, the successfully developed and practical automatic instrument will only supplement present equipment, in the same way that present equipment now supplements and does not displace the usual surveying instruments used on the ground.

e. Clair L. Arneson, U. S. Forest Service, stated that as yet automation of photogrammetric instruments was not particularly adaptable to highway work. The orthophotoscope, which is good for scan line work in removing relief and tilt displacement of images from aerial photographs, is not a contour measuring and delineating instrument and is two steps away from being an automatic instrument.

f. Mr. Pryor said that automated photogrammetric measuring and plotting instruments require vast improvement and perhaps radical changes before they would be sufficiently accurate and reliable. Consequently, it may be many years before automation is attained. In the meantime, the available, effectively proven instruments should continue to be used and improved.

12TH MEETING, JULY 11-13, 1962
(San Francisco, Calif.)

1. The committee was called to order by William T. Pryor, Acting Chairman.

2. John O. Eichler said he had written to 20 universities to request a brief report on research in the aerial surveys field. By July 5, 1962, six replies had been received:

Cornell—analytical and cadastral photogrammetry and photographic interpretation;
Illinois—ground control surveys and deviation of plumb line from the vertical;
Georgia Tech—computation of primary and secondary control data and investigation of uses of photograph-measured coordinates in electronic computers to ascertain supplemental control;
M.I.T.—electronic computer programs for utilization of digital terrain model dimensions in design of highway locations on selected routes:
Ohio State—uses of the stereotope, analysis of the survey control network data, and investigation of uses for photogrammetry in making rights-of-way surveys; and

Princeton—beginning research, but lacking data for reporting plans or accomplishments at this time.

The major problem is getting money for research at universities. If funds could be obtained on a programed basis for specific purposes, getting research under way and keeping it progressing would be easy and of benefit to everyone.

a. George P. Katibah said pure mathematical research in photogrammetry would be of inestimable benefit, not only to engineers using aerial surveys for highway engineering purposes, but also to people engaged in the many other fields in which photogrammetry is used.

b. Lloyd O. Herd, Ohio Department of Highways, remarked good research in photogrammetric engineering was being done by Gottfried Konecny at the University of New Brunswick, Canada. He further remarked it is important that research be planned and conducted for use and improvement of aerial surveys for making traffic surveys and for right-of-way surveys.

c. Olin W. Mintzer said the Ohio State University is doing research for the Ohio Department of Highways so that the latter can plan and program its highway engineering work to get the most economical and best possible results from aerial surveys. The Ohio State University has courses in the third year of the surveying program comprising 14 quarter credit hours, four of which pertain to the basic principles of photogrammetry. Photographic interpretation is a graduate course, but can be taken by undergraduate students. In addition, in the Division of Geodetic Science there are many graduate courses and students also do research in various aspects of geodesy and surveying applicable to highway engineering. The graduate program for photogrammetry will be developed in the Department of Civil Engineering.

d. Mr. Herd mentioned theses on photogrammetry published by Syracuse University are good examples of results achieved at universities. Theoretical photogrammetry is an excellent basis for formulation of electronic computer programs. The book "Elements of Aerial Photogrammetry," by Professor Earl Church, published in 1944 by the Syracuse University Press, is an excellent example, as is work done by G. C. Tewinkel and associates at the U. S. Coast and Geodetic Survey.

e. Robert E. Altenhofen, U. S. Geological Survey, said Herget's method, as developed at the Ohio State University, is used by the U. S. Geological Survey for analytical computation of aerial triangulation problems. Although Tewinkel measured photographic coordinates for electronic computation purposes by the monocular Mann stereocomparator, the points are first selected and designated by stereoscopic examination of the successive pairs of aerial photographs which will be used in aerial triangulation. The photographic coordinate measurements are made by the Schmidt method.

From 20 to 40 percent of the aerial photography now used by the U. S. Geological Survey for topographic mapping is obliquely convergent in line of aircraft flight. Convergent photography is especially advantageous throughout open, rolling topography. It cannot be used effectively where the ground is covered by trees and where the topography is rugged. Experience thus far has proven a c-factor of 1,200 can be depended on for topographic mapping with a contour interval of 5 ft when convergent photography, taken with a 6-in. focal length, wide angle, aerial camera, is used. Such photography is better than super wide angle vertical photography for the 5-ft contour interval topographic mapping done by the U. S. Geological Survey. Nevertheless, wherever convergent photography can be used, super wide angle photography can be used successfully.

f. Mr. Herd stated research by the Ohio State University will include aerial triangulation to ascertain its practical uses for highway survey purposes and right-of-way acquisition. Work to be undertaken will cost about $42,000.

g. Mr. Pryor gave a brief explanation of the history of research problem statements. (Twelve research problem statements were published in HRB Correlation Service Circ. 428 in Sept. 1960 as Memo. 2 of the Committee and five additional statements were published in Circ. 480 in Sept. 1962 as Memo. 4.) Preparation of research problem statements was initiated to assemble and record in concise factual form a description of the general problem, a specific statement of work to be undertaken, a list of the factors involved, and a summarization of the research and data needed, supported whenever feasible with the listing of selected references. Subcommittees responsible for review of the initial draft of the statements should examine them carefully to ascertain whether or not the four separate divisions are clear, concise, easily understood, and pertain specifically to the factors involved. Fully used, each statement would enable engineers employing aerial surveys to judge which specific type of research is most important to them and to select for guidance the specific statements applicable to accomplishing the research undertaken.

h. Mr. Katibah mentioned the thesis by John W. Lund, of May 21, 1962, "Aerial Road Inventories," prepared at the University of California. This is a good example of the use of one of the research problem statements.

i. Charles E. McNoldy suggested engineering schools be requested to undertake research, guided by research problem statements prepared by the committee. Moreover, these statements could serve as guides in preparation of graduate theses. Requests could be made that copies of the theses be made available to the Committee.

j. Mr. Pryor said State highway departments should initiate research projects, supported by appropriate research problem statements. For approved projects, Highway Planning Survey funds can be used and matched in the same proportion as prescribed by law for the separate types of highway construction funds, interstate, primary, and secondary.

3. Research in utilization of aerial surveys for right-of-way purposes was discussed.

a. L. L. Funk, Planning Engineer, California Division of Highways, remarked survey ties are made to property corners in accomplishing right-of-way measurements by photogrammetry. Photogrammetrically compiled maps are the essential basis used in making these instruments.

b. Mr. Herd said the Ohio Department of Highways has an electronic computer program for traverse surveys and for computing plane coordinates from such surveys. Also the State has an electronic computer program for computing metes and bounds descriptions to be used as right-of-way records from field surveys. There is no reason why these computer programs cannot utilize photogrammetric measurements, as well as field survey measurements, for right-of-way purposes.

c. Professor Eichler remarked the Highway Research Correlation Service Circular 418 for March 1960, by the Committee on Land Acquisition and Control of Highway Access and Adjacent Areas, contains a paper by Vern Segelke on the use of photogrammetry for highway land acquisition purposes as well as a bibliography on uses of aerial surveys for, and in making such surveys for, procurement of highway right-of-way.

d. Mr. Pryor explained the method used in Bavaria in 1960 for making cadastral surveys by photogrammetric methods. Property corners and lines are monumented on the ground. Photographic targets are placed on each property marker. Also photographic targets are placed over basic geodetic control markers within and near the area of aerial survey. Then aerial vertical photographs are taken to provide stereoscopic coverage of the area at a scale ranging between 1:9,000 and 1:10,000; the larger scale is used for the portions of highest relief and the smaller scale for those of lowest elevation. The cadastral measurements (made photogrammetrically with a Stereoplanigraph using 1:9,600-scale aerial photography) are accomplished at the scale of 1:2,000. The survey area had previously been mapped topographically at a scale of 1:5,000. Generally, the photography, taken after the targets had been set on the ground, has an endlap of about 60 percent and a sidelap of about 35 percent. An aerial camera of 8¼-in. focal length, taking photographs at the format size of 18 by 18 cm (7.1 by 7.1 in.) is used to reduce the perspective layover of trees, buildings, and rugged topography, and thus reduce ground obscuration.

The photographic targets are constructed of circles of white cloth or plastic, 32 cm (12.6 in.) in diameter. Four round disks are placed symmetrically, as at the corners of a square, on opposite sides of the control point or the property marker. The open area between the white disks is centered on the marker of the property or control point for which it is set. The supplemental horizontal and vertical controls are established for each stereoscopic model by aerial triangulation, using stereoscopic model measurements made with the Stereoplanigraph initially oriented on basic control in the first of several stereoscopic models in each aerial triangulation strip. The aerial triangulation strips for which the successive stereoscopic model measurements are made are adjusted in strips of from four to six stereoscopic models. Mean values are used between separate adjacent strips of photographs. By means of the Stereoplanigraph, 200 separate points are measured in each of two 7-hr shifts per working day. Each point is measured twice, working sequentially forward and then backward in numerical order. Consequently, 400 measurements are accomplished per day per instrument operator.

The instrument measurements made are typed by an automatic electric typewriter. These X, Y, and Z measurements are transferred to punch tape and introduced into a computer. The computer utilizes the mean square adjustment procedure in reconciling the two sets of measurements. The tabulation of results contains the identification of each point, the mean square adjustments and the X and Y plane coordinates. The mean square adjustments are determined from the separate measurements made for each point. Cadastral mapping accomplished in this manner comprises approximately 30,000 ha (116 sq mi) per year.

The X and Y plane coordinates of the property corners and lines thus measured and computed are recorded in the Government offices having jurisdiction. These constitute the legal documents of property boundaries. From such plane coordinates the actual areas of ownership are computed.

e. Mr. Katibah remarked that only a few years ago it was difficult to get plane coordinates, determined from ground surveys, accepted. Now few people question the use of such coordinates and many use them exclusively.

f. Richard E. Futrell said premarked property corners are measured photogrammetrically in the State of Washington, and such measurements will be accepted.

g. Mr. Altenhofen said the Bureau of Land Management accepted photogrammetric measurements of land survey section corners made by the U. S. Geological Survey. These measurements were made by bridging techniques to ascertain the possibility of setting section corners on the ground in reference to objects for which horizontal position had been measured photogrammetrically. The place for setting each section corner was established by horizontal distance intersection from three separate images of nearby ground objects. These measurement distances were determined by computation, after measuring the plane coordinate position of each of the three reference objects. The actual section corners were established on the ground in southeast Utah from these measurements.

h. W. S. Higginson mentioned Lebanon is proposing to have its entire country photographed and mapped. Aerial photography and mapping would determine where plane coordinate measurements must be made for establishing property corners. Each corner, of course, would be found and targeted before photography so that the photogrammetric measurements could be made effectively.

4. Mr. Katibah gave an oral report on use of the Auto-trol digital terrain scaler by California Division of Highways. The Auto-trol cost $7,000 including an extra digit in the readout system. The Benson-Lehner instrument (manufactured for similar purposes) costs more than $11,000. Since correction of minor manufacturer's deficiences, only occasional minor breakdowns have occurred in the past 5 mo. Tubes are used in the instrument instead of transistors. The Auto-trol has served well over the types of topography where good topographic maps are compiled at the scale of 50 ft to 1 in. with a contour interval of 2 ft, or an appropriate number of spot elevations in lieu of contours are obtained by photogrammetric measurements. The Auto-trol facilities measuring and recording of cross-section measurements in sufficient detail and accuracy for computation of construction pay quantities. Wherever the topography is especially rugged and difficult to map, the Auto-trol is used. It is especially effective where maps of the same area, compiled at a scale of 100 ft to 1 in. with a contour interval of 5 ft, were used for initial design purposes, but the mapping accuracy is not deemed sufficient for measuring cross-sections. Usually the centerline, as designed by use of the previously compiled topographic maps, is staked on the ground, and photographic targets are set along the staked centerline and at other appropriate places. In measuring cross-sections for detailed design and determining construction quantities, the

Auto-trol is indexed on this line using photographs taken after staking and targeting.

The California Division of Highways makes construction payments on the basis of each staked cross-section measured from the design plans. Deviations from these measurements are necessary, however, in areas where unpreventable slides occur and where changes in highway alignment and/or grades are made by the construction engineer. Construction quantities measured by photogrammetric methods, when highway construction is in progress, are utilized in making payments on projects where the volumes of earthwork are large and along construction segments where slides occur due to unforeseen slope instability or excessive rainfall.

Photographic records are especially valuable at the end of a construction season and at the resumption of construction after a shutdown. Differences shown by the two different sets of photography are accurate representations of changes occurring between those dates. In this way the responsibility can be established for costs incurred in coping with changes when construction is resumed.

The California Division of Highways uses the large-scale topographic maps (100 and 50 ft to 1 in.) for design. Such maps are indispensable in positioning the centerline and in designing the profile gradients.

a. Mr. D. Shelby asked whether topographic maps of the 100 ft to 1-in. scale with a contour interval of 5 ft could not be used exclusively for design. Then, once the centerline had been staked on the ground, adequately targeted, and new photographs taken, the Auto-trol could be used for measurement of cross-sections to compute the volumes of earthwork and construction pay quantities.

b. Mr. Katibah replied that there are certain types of topography and land use where maps at the scale of 100 ft to 1 in. would not fulfill California requirements, and topographic maps at the scale of 50 ft to 1 in. are required.

c. Mr. Funk added that topographic maps at the scale of 100 ft to 1 in. have been adequate where the topography is rugged, but topographic maps at the scale of 50 ft to 1 in. are essential in areas where the topography is not rugged and land use is intense.

d. Mr. Katibah said in using Auto-trol with double-projection photogrammetric instruments, cross-section data on dredge pile and tailings areas were measured which were superior in quality to cross-sections measured by survey parties working on the ground. Measurement of borrow sites before and after removal of construction quantities by the Auto-trol has been effective. As an example, one borrow pit, approximately 1,000 ft wide and ½ mi long was measured in 2 days.

e. Mr. Herd remarked that in Ohio, the maps are used to design the highway location centerline. The centerline is staked on the ground, appropriately targeted, and aerial photographs are taken. These aerial photographs are used in double-projection instruments and cross-sections are measured by use of the Benson-Lehner scaling and recording device.

f. Mr. Funk said the accuracy of maps compiled by photogrammetric methods in California was sufficient for designing the location. Establishing and accurately positioning the centerline for the highway on the maps is a vital phase of this work. Cross-section measurements are made on the topographic maps when they are of sufficient scale and small enough contour interval. In other cases, the design centerline is plotted on the manuscript oriented for measurement of cross-sections on the stereoscopic models by use of the Auto-trol. By such procedures, the need and expense of staking the centerline on the ground for design purposes are eliminated.

g. Dwight E. Winsor said, in Region 9 of the U. S. Bureau of Public Roads, the distance computed to slope stakes on photogrammetrically measured cross-sections is used in setting slope stakes on the ground. The measurements are made horizontally after the centerline has been staked. Experience has indicated that 80 percent of the slope-stake points "catch" within 0.2 ft. Only 20 percent of the points require a slight change in position of the slope stakes to get their cut and fill positions to agree on the ground with the distance from centerline and the height above or below profile grade on the computed slope.

h. Mr. Futrell said his experience in Washington has been similar. Less than 3 percent of the points computed for slope-stake position, using photogrammetrically measured cross-sections, have questionable positioning when staked in the field by use of the computed distances.

i. Mr. Katibah stated the California Division of Highways plans to compare the accuracy of measurement of earthwork quantities from topographic maps compiled at the scales of 50 and 100 ft to 1 in. with cross-section measurements made by use of the Auto-trol. These comparisons will be made where the topography is rough.

j. Joe V. Evans, Photogrammetric Engineer, State Highway Department of Georgia, said it would be desirable to compare production and accuracy of the Auto-trol and the Benson-Lehner instruments used in conjunction with the Kelsh stereoscopic plotter to measure cross-sections.

k. Glenn Anschutz said a Kelsh cross-section measuring attachment, the first one sold by the Kelsh Instrument Co., was recently placed in operation in Kansas. Initially, an Auto-trol was to be purchased, but procurement policy made it necessary to accept the low bid of $5,800. Among the troubles encountered in use of the Kelsh measuring device were reading one measurement value and another being punched out. Rigorous tests, however, indicated that the punched out value, and not the visually read value, was correct. Once this situation was understood the instrument seemed to have considerable merit. It has the added feature, as compared to the Benson-Lehner and Auto-trol instruments, that X measurements may be made as well as Y and Z. Therefore, the three space measurements, often needed by engineers, are easily accomplished. Another operational difficulty is the fact that one punch card is often insufficient for recording points measured on one cross-section, and carrying forward the needed measurements onto another card is difficult.

l. Mr. Funk stated that problems encountered in the measurement of cross-sections with such devices in timber-covered areas can be reduced by setting targets on the ground before aerial photographs are taken and photogrammetrically compiling topographic maps at scales of either 100 or 50 ft to 1 in. Measurements are then made to the points that can be seen between the trees. Where the timber is too dense, essential measurements can be made on the ground using the targeted control points as origin. An initial design is then made, clearing limits are established, centerline is staked, and clearing is accomplished by contract where necessary. After clearing, appropriate photographic targets are set, new photographs are taken, and the highway construction zone is measured photogrammetrically.

m. Mr. Katibah said the California Division of Highways had standardized for practicable reasons on use of 6-in. focal length aerial photography, because nearly all photogrammetric and aerial photography firms working in California are equipped for this photography.

n. Mr. Funk remarked photography contracts for the California Division of Highways survey projects are awarded on a standby basis for all projects throughout the State. Thus, whenever photographs are needed, the only action required is notice to the contractor. He will then proceed to the project and take the photographs.

o. Theral R. Nielsen, U. S. Forest Service, said the Forest Service had abandoned measuring cross-sections by photogrammetric methods in heavy timber areas until after clearing has been completed.

p. Fred B. Bales said it was general practice in Virginia to photogrammetrically measure cross-section points between trees, in tree-covered areas, where the ground is visible. Between such points the cross-section measurements are completed by surveys on the ground after the designed centerline for the highway has been staked.

5. Mr. Katibah said experience in California had substantiated the desirability of having all highway surveys tied, when they are initially made, to the State plane coordinate system. In this way, the highway surveys become an extension of the national network of basic control and closures obtained indicate the accuracy of the highway surveys.

a. Mr. Herd said the Ohio Department of Highways objective is to eventually have all permanent station markers established in making highway surveys accurately tied to the system of plane coordinates found most suitable for Ohio.

b. Mr. Pryor reported that as a result of the Federal-Aid Highway Act of 1956, Federal-State highway funds may be utilized for the establishment of temporary and permanent geodetic markers in accordance with specifications of the U. S. Coast and Geodetic Survey. The establishment would be along existing or proposed highway routes where needed for the accomplishment of each highway survey. Policy and Procedure Memorandum 20-9, issued May 13, 1957, and as amended by PPM Memorandum 20-9(1), issued Nov. 29, 1960, contains details regarding the manner in which control survey projects may be initiated, the recommended spacing of station markers and bench marks, and size of control survey projects. Whereas control surveys can be accomplished for any type of highway on the established systems, interstate, primary, and secondary, PPM 20-9(1) gives priority to the establishment of geodetic markers for interstate highway routes. To qualify for Federal-aid participation, highway survey project control surveys must be accomplished in accordance with U. S. Coast and Geodetic Survey specifications. Geodetic markers may be established for highway survey purposes by the U. S. Coast and Geodetic Survey forces or by qualified survey crews assigned to such work by the State highway departments.

6. Mr. Pryor described the history of the "Reference Guide Outline." The Photogrammetry for Highways Committee was established in the American Society of Photogrammetry in 1950. Initial work undertaken by this committee was preparation of the specifications for aerial photography and mapping by photogrammetric methods for highway engineering. At that time, it was anticipated much of the photogrammetry for highway surveys would be accomplished by photogrammetric engineering firms under contract. Accordingly, the format of the specifications eventually devised was patterned after specifications for highway construction. There are two major divisions: Division I pertains to general requirements including definitions, proposal requirements and conditions, execution and award of contract, scope of work, control of work and materials, legal relations and responsibility of the contractor, prosecution and progress, and measurement and payment; Division II contains numerous sections of detailed specifications dealing with such subjects as aerial photography, photographic prints, indexes, mosaics, topographic and planimetric maps, ground control surveys, station markers and bench marks, and the test of ground control surveys and maps. In the proposal schedule, each item of work was related by corresponding number to its applicable section in the specifications. In preparing the draft, use was made of some basic suggestions from the subcommittees responsible for legal and administrative matters, aerial photography, photographic preparations from aerial photographs, and topographic mapping and ground control surveys. First publication was in 1956 and a revision was published in 1958, both under the sponsorship of the American Society of Photogrammetry and the American Congress on Surveying and Mapping.

7. Professor Mintzer commented on some of the research undertaken by the Ohio State University for the Ohio Department of Highways. One project is to combine the techniques of geophysics and photographic interpretation to make soils surveys in the reconnaissance survey stages and in the preliminary survey and design stage of highway location. Techniques and procedures will be developed for utilization of geophysics and resistivity measurements to determine depths of construction materials within the bounds of soil-type areas ascertained by photographic interpretation. Also, criteria will be developed for determining where and under what conditions borings should be made to supplement the resistivity measurements. Borings, on a selective basis, will provide representative samples of materials for laboratory testing.

8. Information concerning use of photogrammetry in various States, supplementary to that contained in Part I of this Special Report, was given by committee members and other interested persons:

a. Mr. Anschutz said a materials survey is being made of ten counties in Kansas by the State highway commission using photographic interpretation techniques. These counties will be photographed next fall. Ten percent of the sites selected by such techniques as being potential sources of suitable construction materials will be sampled and laboratory tested. Eventually 105 counties of the State will be fully surveyed to ascertain sites of suitable construction materials through a combination of photographic interpretation and field sampling and testing. Experience thus far has proven wherever only a few sites are known, many more may be found. Thus far, no potential sites of construction materials have been missed when the combination of photographic interpretation and field checking has been applied.

Using the Kelsh cross-section measuring attachment (See Sect. 4k, Minutes of 12th Meeting) computed construction quantities differed by only 0.2 percent from those of measurements made on the ground, where comparisons have been possible. On one 20-mi test project, the cross-sections were measured by photogrammetric methods; 10 percent of these were precision measured on the ground by conventional methods. It has been concluded from this test that photogrammetric measurements, on an over-all basis, were better than measurements made on the ground. Differences in construction quantities from these separate measurements, converted to construction dollars, amounted to less than the cost of measuring the cross-sections on the ground.

In photogrammetric work with the Kelsh double-projection instrument, new color filters with the glass specifically ground to accommodate the eyes of each separate instrument operator greatly improved the stereoscopic models, the accuracy with which the models can be measured, and the ease of operation. Tests are being made with the present five projectors using glass plate transparencies printed by three separate methods: the Kelsh Fluoro-dodge, Log-Electronic, and the usual contact printers. Results are not yet conclusive.

(1) Mr. Bales said the Virginia Department of Highways has also been using glasses ground to an ophthalmologist prescription for each instrument operator to achieve the best possible color separation of images forming the stereoscopic model. Results from this type of spectacles are much superior to those achieved by using unground glass, especially in comfort for the instrument operator.

(2) Mr. Altenhofen said the U. S. Geological Survey was planning to get color spectacles ground to prescription for each instrument operator in its Rocky Mountain region.

(3) Mr. Herd said the Ohio Department of Highways uses the Bausch and Lomb Orthorater test to select physically well-qualified photogrammetric instrument operators.

(4) Mr. Anschutz continued by saying engineers and geologists in Kansas were interpreting stereoscopic models in the Kelsh instruments as the maps were compiled. Checks are made on the ground to verify the interpretations. Success thus far has been remarkable. The maps contain contours depicting the ground surface and delineating the various beds of underlying materials. On one interstate project 24 mi long, with 24 large structures, the excavation price was only $0.13/cu yd. This low price, one-half the engineers' estimate, is a consequence of construction contractors having the geology maps available at the time they were preparing their bids.

b. Sidney Bertram of the RW Division, Thompson-Ramo-Wooldridge, Inc., reported on automatic map compilation.

Two instruments have been developed, the Automatic Stereomapper and Automatic Map Compilation System.

In the Automatic Stereomapper, an elementary mechanical scanner (Nipkow disk) is arranged to simultaneously scan the conjugate images of the stereoscopic model formed by intersection of rays projected by the Kelsh instrument. When the stereoscopic model has been leveled and scaled to the field-surveyed control, the instrument automatically follows the stereoscopic model of the ground and features on it along the successive profiles. As each profile is measured an orthophotograph and a graphical delineation between successive contour elevations are produced simultaneously. The planimetric profile delineations, repeated in alternating sequence, are successively a heavy line, a light line, and no line. The place of change from one delineation to another is a contour position—a contour intercept on the measured profile. In essence, a physical measurement is being made automatically by the Stereomapper while planimetric data are recorded as an orthophotograph, and the successive contour intercepts are identified and marked in measured strips.

In the Automatic Map Compilation System, the use of a stereoscopic model is obviated by the application of a small electronic digital computer. The instrument operates in a profiling mode similar to the Stereomapper. At each ground X and Y position, the computer uses the elevation values already established in the vicinity of the conjugate image of the stereoscopic pair being measured to estimate the new value.

The electronic computer thus has a ground X and Y measurement and Z estimate point from which it is able to compute the photographic coordinates, x, y, and x', where the point is to be found and to direct an analog scan to the appropriate area in each photograph. The associated analog system then establishes the correct elevation for the point so the computer can proceed with the calculations for the next point.

The information from the scan is used to recreate the photographic image element for each finite point to expose the appropriate area of a negative to print the orthophotograph. Simultaneously, the electronic computer provides height information to create the profile pattern by planimetric graphical delineation between successive contour intercepts along each profile segment, as also accomplished by the Stereomapper.

To insure that the photographic elements will fit together properly on the orthophotograph, the scans on the two transparent positive photographs printed on glass plates are dynamically varied to conform in appropriate manner to the elevation and slope of the ground. Thus, elements on each photograph of high ground elevation will be observed with a large scan, whereas those of low ground elevation will be observed with a small scan. Similarly, sloping ground will be observed with a parallelogram-type scan skewed (sloped) appropriately to the direction of the ground slope.

The Automatic Stereomapper is limited by the characteristics of the Kelsh stereoscopic plotter and the problems inherent in an analog model. Ground slopes along the line of flight can be accommodated to improve the orthophotograph by sloping the scanning system, but the sloping is limited to an angle of 45° at the center and 20° at the edge of the stereoscopic model. This range in sloping of the scanning system of the instrument does not limit the ability of the instrument to follow steeper slopes.

Because the Automatic Stereomapper operates with a fully developed analog model, the operator has a normal stereoscopic model available for visual examination. The Automatic Map Compilation System uses a twin-TV system to provide the operator with an electronically repeated stereoscopic model of the area under observation, so that he can monitor the automatic movements of the instrument during operation.

c. Marshall S. Wright commented the Army Map Service uses the three-projector Kelsh instrument for revision of maps in their updating operations. The three projectors are more convenient and effective in orienting the stereoscopic models to the horizontal and vertical control than two projectors only.

Mr. Katibah substantiated the foregoing comment. The three-projector Kelsh instrument reduces the amount of horizontal control needed for the absolute orientation of two stereoscopic models. The two-projector instrument is preferred for mapping work.

d. Mr. Pryor explained briefly the manner in which the three-projector Kelsh instrument is used by the Aerial Surveys Branch of the U. S. Bureau of Public Roads in preparation and use of slotted stereotemplates for bridging horizontal control.

Successively, each two stereoscopic models are initially leveled and scaled as a unit to the best available control. For preparing the stereoscopic model templates, supplemental control needed for the initial scaling of each pair of stereoscopic models is established in either one of two ways, depending on the length of the project and the manner in which continuing and adjacent flight strips of photographs overlap each other. Where survey projects are small, usually within the boundaries of one flight strip, one stereoscopic model is leveled and scaled to ground control. Succeeding models are scaled to pass points easily identified in both stereoscopic models. When survey projects are long, use of pass points only sometimes results in leveling difficulties because of progressive enlargement or reduction in scale from one stereoscopic model to another. Whenever horizontal scale becomes considerably different from the scale at which the leveling measurements are being made, stereoscopic models cannot be leveled adequately. Consequently, when projects are large and where the adjoining flight strips lack sufficient overlapping coverage for effective use of pass points from one stereoscopic model to another, the needed supplemental control for initial scaling of the stereoscopic models is established by means of a preliminary radial plot assembly of contact print size slotted templates.

Having established the initial horizontal control as needed, the radial point origin and radial points are selected for each photograph as it is used in succession to form two stereoscopic models. Because there is no assurance without exact scale of achieving truly leveled stereoscopic models, an identifiable image near the "nadir point" is used as radial point origin in preparing the templates. The approximate position of the "nadir point" of each photograph is determined by centering the shadow cast by the platen of an elevation stand of the type used in the Zeiss multiplex aeroprojector equipment onto a circle drafted on a piece of heavy paper centered and fixed to the bottom of the stand. The stand is maneuvered to the "nadir point" position by using the light of the projector involved after switching off the other projector.

The radial points and origins are marked from the stereoscopic models onto the matte surface side of a translucent polyester sheet. At least nine points are chosen for each photograph, including an image point at or near the "nadir point" to serve as the radial point origin of the slotted template to be made for each central photograph of each successive pair of stereoscopic models, the conjugate image of the "nadir point" of the preceding and succeeding photograph, two pass points on opposite sides of the photograph center at proper position in the outer one-third to one-fourth of each one-half of the photograph in the center projector, the conjugate images of pass points of the preceding and succeeding photographs, and horizontal control points. By symbol and by color, the separate points for each photograph are placed on the same polyester sheet. In this way, one sheet becomes the radial plot template record for each survey project. From the polyester sheet, each set of points of the same symbol and color are pinpricked onto a 33- by 40-in. flat cardboard of $\frac{1}{20}$-in. thickness. The center radial point origin hole is punched, and after the slot-cutting tool is separately centered on each pinpricked radial point, the radial slots are cut.

The stereoscopic model templates are assembled, beginning with the stereoscopic model containing the largest number of field surveyed horizontal control points, from there to the next horizontal control point, and to each end of the survey project.

The base for the radial plot assembly is comprised of polyester sheets with fine lines spaced 5 in. apart in both X and Y directions and etched on the smooth side of the sheets, which are fitted carefully together to form a plane coordinate grid system. These etched lines are on the underside and are filled with red wax so they may be seen easily but not marred by the marking and erasing of points on the matte side, which is up. In this manner the plane coordinate grid system may be reused for each successive survey project on which a radial plot bridge is made.

To control the radial plot assembly, studs representing the basic horizontal control points of the survey project are pinpointed over their plane coordinate plotted positions and are supported by a 1-in. square cardboard (with a 0.15- in. diam hole punched in its center by the template cutter) cemented to a 2-in. square cardboard containing a 0.6-in. diam hole. This easily constructed support is positioned securely with rubber cement to the grid base. The supports are allowed to set for a number of hours before making the radial plot assembly.

After completion of the assembly, the intersection of the radial slots and "nadir points" are marked onto the matte surface of the gridded polyester sheets by inserting, after moistening the marking end, an extra thin (0.04-in. diam) black or colored lead in the hole of each stud. The X and Y plane coordinates of each point marked on plane coordinate grid system are measured and recorded.

Each point constituting radial plot established horizontal control for each stereoscopic model is pinpricked and identified by a representative symbol and color on a stereoscopic-model-size polyester sheet. This transfer sheet contains the relative horizontal position of each point of both natural and target images used in preparing the stereoscopic model templates and in assembling the radial plot. Each mapping stereoscopic model is then scaled to the positions of the affected points by placing the polyester transfer sheet on the mapping surface of the Kelsh instrument.

By this procedure supplemental horizontal control is bridged and is used in 200, 100, and 50 ft to 1-in. scale mapping, as required on each survey project. In many cases, where errors in the basic horizontal control of the survey project have been ascertained by this procedure in magnitude and in direction, checking in the field by survey parties has substantiated findings from the radial plot. Consequently, an added benefit from this procedure is elimination, before the mapping is undertaken, of gross errors in survey project control.

(1) Mr. Anschutz said Kansas has two three-projector Kelsh instruments for compiling maps. Additional uses, however, are made of the three-projector instruments which have more than justified their cost. The pair of stereoscopic models formed in the three-projector instruments are more easily oriented to highway centerline control than is the single stereoscopic model of the two-projector instruments. Borrow-pit areas are more easily mapped with the three-projector instruments, especially where the area is not confined within the bounds of one stereoscopic model.

(2) Mr. Pryor explained the advantages of having interchangeable projection cones for the double-projection instruments. Projection cones may be obtained for using aerial photographs taken with a 6-in. focal length camera at a 5- and a 7-diam projection ratio, or for using those taken with an 8¼-in. focal length camera at a 5-diam instead of a 4-diam projection ratio. The significant advantages in having the three sets of interchangeable projection cones are:

(a) Aerial photographs taken at a smaller or larger scale than specified may be used, rather than to wait many months until the next photography season to get new photography at the desirable scale. Photographs of 6-in. focal length taken for mapping on a 5-diam projection basis, but which are too small in scale, can be used in the 7-diam projection ratio projectors. Photographs of the same focal length taken with the intent of mapping on a 7-diam projection basis, which are too large in scale for the purpose, can be used in the projectors designed for a 5-diam projection ratio. Thus, a season's delay and difficulties otherwise inherent in mapping at an odd scale and photographically enlarging or reducing to achieve the desired uniform scale are avoided.

Photography of 8¼-in. focal length can be used in the projection cones to map areas where tree cover is rather dense. Less ground would be obscured than if the same area were photographed with an aerial camera of 6-in. focal length. The same cones can be used to compile reconnaissance-type maps from U. S. Department of Agriculture photography.

(b) Interchangeable cones allow compliance with the relief height to flight height ratio in rugged areas where desired map scale could not be achieved from the 5-diam projection ratio and 6-in. focal length photography, but can be from the 7-diam ratio and the same focal length photography or from the 5-diam projection ratio using 8¼-in. focal length photography. The larger projection ratio used with 6-in. focal length photography and the 5-diam projection ratio with 8¼-in. focal length photography permits a larger flight height for the same scale of mapping, thus accommodating a larger relief height in each stereoscopic model. Examples of flight heights and relief heights possible with the various focal length photography and projection ratios are given in Table 1. It is evident there is a limit on mapping scale and relief height that can be accommodated by the double projection instruments. Where reflief is quite large, the limits more readily occur under the 5:1 than under the 7:1 projection ratio use of 6-in. focal length photography. The 5:1 projection ratio and 8¼-in. focal length photography accommodate an intermediate relief height to flight height condition.

e. Mr. Funk reported the California Division of Highways establishes basic horizontal control for each highway survey project with a Geodimeter. The Division designs the flight lines for each survey project to assure photography of the desired area at the scale required by the purpose for which it will be used.

All photogrammetrically compiled maps are checked for accuracy and completeness by photogrammetric methods. In this way, the over-all quality of the maps is ascertained more adequately, satisfactorily, and with less expense than can be done on the ground.

In some districts, the California Division of Highways has begun to establish supplemental control for the photogrammetric compilation of maps in establishing the basic control. Heretofore, each photogrammetric firm awarded a contract has been responsible for establishing all supplemental control essential for leveling and scaling each stereoscopic model on survey projects where aerial photogrammetric methods were employed.

The Division has an Aristo Coordinatograph on order, which will accommodate a measurement area of 59 by 79 in. The Stereoplanigraph received this year is to be used for measuring supplemental control and for testing the accuracy of maps compiled photogrammetrically.

TABLE 1

POSSIBLE FACTORS IN MAPPING FROM AERIAL PHOTOGRAPHY

Scale (ft to 1 in.)	Flight Ht (ft)	Relief Ht (ft)	Focal Length (in.)	Projection Ratio[a]
100	3,000	750	6	5 1
100	4,200	920	6	7 1
100	4,125	870	8¼	5 1
50	1,500	375	6	5 1
50	2,100	460	6	7 1
50	2,060	435	8¼	5 1

[a]Projection ratio is number of times map compilation scale is larger than photography scale

The supervising photogrammetric engineer position has been upgraded so the equality with supervising highway engineers of qualifications and responsibilities has become recognized.

f. Mr. Futrell reported the Washington Department of Highways has made good progress in the past 4 yr. The Department now has three double-projection photogrammetric instruments, a three-projector Balplex 760, and two Kelsh stereoscopic plotters—a two- and a three-projector type. The State also has a reduction printer for printing the reduced size transparencies used in the Balplex instrument and has a Kelsh Fluoro-dodge-type printer on order for automatic dodging in printing 9- by 9-in. glass plate transparencies for use in the Kelsh instruments. Two layout tables with 10-in. plane coordinate grids etched in the formica tops are used.

The basic control for each highway survey project, where photogrammetric methods are to be employed, is surveyed by use of a Tellurometer, two Wild T-2 theodolites, and two self-leveling levels, supplemented by a subtense bar. Photographic targets are placed on the ground over the markers of basic control points before photography. This is done for all points surveyed previous to photography and for all points where basic control will be required after photography.

Aerial photography contracts are negotiated on a Statewide basis. A work order is issued whenever photographs are required on a particular project. Within the various items of work provided in the Statewide contract, the project work order contains the specific items by location, scale, area, etc. At present, most of the photogrammetric work required by the Department of Highways is done by State personnel and equipment. The large "overload" jobs are still contracted to qualified firms. As the photogrammetric work is done by the State, tests are being conducted to determine the limits at which control can be eliminated.

On some projects, where the ground is not obstructed by vegetation, slope staking has been governed by the measurements made photogrammetrically on the stereoscopic models. Also, where feasible, cross-sections for computation of grading quantities and setting construction slope stakes will be measured photogrammetrically after clearing ground initially obscured. Experience thus far has indicated differences of less than 3 percent will occur between grading quantities measured by surveys on the ground and by photogrammetric methods. Results have been especially good wherever the topography is rugged.

Right-of-way plans and property descriptions are being prepared, and land areas computed from measurements made by photogrammetric methods. The property corners and lines are targeted before photography.

Each highway location project is surveyed by aerial or ground survey methods. Choice of method is governed by season when work is started, urgency, character of topography, ground cover, and accessibility.

The scale and contour interval of topographic maps are chosen by character of topography and land use and by the engineering stage in which the maps are to be used. Generally, for reconnaissance surveys to determine and compare routes, the scales are 400 ft to 1 in. with a 10-ft contour interval in rural areas and 200 ft to 1 in. with a 5-ft contour interval in urban areas. In the preliminary survey stage for highway design and preparation of construction plans, a scale of 100 ft to 1 in. with a contour interval of 2.5 or 5 ft, depending on ruggedness of the ground, is most often used.

Where larger scale maps are necessary, topographic maps at the scale of 50 ft to 1 in. with a contour interval of 2 ft are compiled, or planimetric maps are compiled and profile and cross-sections are measured at that scale. For bridge sites, maps are compiled at a scale of 40 ft to 1 in. with a contour interval of 1 ft. Most map sheets compiled by photogrammetric methods for highway design purposes are 36 by 80 in., and all are compiled on scale stable polyester base sheets.

(1) David S. Johnson said Connecticut uses large-scale aerial photography as an aid in making property appraisals but not for right-of-way documents.

(2) Mr. Shelby stated Texas had had good success in use of photogrammetric methods in preparation of right-of-way deeds for 40 separate parcels of property.

(3) Mr. Funk remarked that in California, property appraisal maps are compiled by photogrammetric methods. Aerial photographs are used as supplements to the maps. Points on property lines and at property corners, after being position determined from their plane coordinates on the maps, are actually surveyed and marked on the ground. The surveyed positions constitute the deed record.

(4) Mr. Futrell continued by saying the Washington Department of Highways prepared a set of specifications based on the "Reference Guide Outline."

Washington ties all highway surveys made using photogrammetric methods to the State plane coordinate system. Moreover, all Government agencies in the State are directed by statute to use this system wherever convenient. Due to large variations in ground elevation throughout many highway survey projects, the datum of the State plane coordinate system is adjusted upward the amount necessary to keep differences between distances computed from the plane coordinates of control points and features on the maps and those measured horizontally between the same points on the ground within 1:5,000 or 1:10,000, whichever accuracy is required. By employing this adjustment procedure, plane coordinates of control points and of each feature give more correct distances. Thus, there is no need for adjustment of each map-plotted or map-computed distance when the designed centerline of the highway and the rights-of-way are staked on the ground.

Acceptance of photogrammetrically made measurements in computing earthwork quantities creates new problems for highway engineers. The weather can hinder the taking of aerial photographs needed for making progress payments during construction and for measuring the surface of materials of different classification as the construction work progresses.

g. The problem of obtaining photogrammetric work by contract was discussed.

(1) Mr. Futrell said the Washington Department of Highways requires prequalified firms to submit both work and price proposals. Each firm is then classified on the basis of past performance, equipment and personnel immediately available for assignment to the required work, and how well the firm may be able to comply with survey project schedules for completion of each phase of the required work.

(2) Mr. McNoldy said the Pennsylvania Department of Highways asks for a proposal from one prequalified firm. The proposal is compared with the engineer's estimate of cost and time schedule for doing the stipulated work. If the proposal is acceptable, a contract award is made. Should the price of the firm invited to submit a proposal be too high, proposals are solicited from other firms, each in succession, until an acceptable price and performance schedule is received.

When price quotations are too low, a contract award should not be made. When a contract is awarded to a firm which has proposed to do the work at a price below costs, savings are not realized by the contracting authority. Instead, "corner cutting" by the contractor is invited, for unless he reduces his expenses he will fail to make enough money to keep his firm in business. Additional costs to the contracting authority may result from unsatisfactory performance in both quality and time of completion. Completion is further delayed when work is rejected, when work is done over and has to be rechecked for accuracy and completeness, and especially when repetition of the cycle is required before work of acceptable quality is attained. The alternative is acceptance of and payment for inferior work not conforming to specifications.

(3) Mr. Wright said extremely low prices are quoted by firms "hungry" for work. In some instances there is no intent to make a profit, merely to get payroll

money to keep the organization going. High prices are quoted by firms already overloaded with work. These firms submit quotations merely to keep the various contracting authorities for whom they still desire to do work aware of their interests and availability.

(4) Mr. Wright said the contracting authority, when justified, should ask for a discussion of prices to ascertain whether or not the proposing firm might be able to reduce its price quotations and still do the required work on schedule and to the stipulated accuracies. This should be done before entertaining any thought of rejecting the proposal and initiating negotiations with another firm.

(5) Mr. Johnson said each State should question prices when and wherever considered necessary. Prices change because of factors such as changes in the character of work required, season of year, weather conditions, schedules for completion, payroll costs of qualified employees, transportation and materials. Two survey projects are seldom identical.

(6) Mr. Pryor remarked there are three principal elements in the negotiation of contracts on a professional basis: consultant selection on the basis of qualifications, agreement on work to be done according to schedule, details, and accuracies; and concurrence on the amount to be paid by the contracting authority to compensate the consultant for all anticipated expenses and provide a reasonable profit.

h. Mr. McNoldy reported that a summer surveying camp will be conducted this year at the University of Pennsylvania. Employees of the Pennsylvania Department of Highways who are or will be assigned to surveying are encouraged to attend. Principles, uses, and operation of the Tellurometer and the Geodimeter will be included, as well as other instruction in field surveying and operation of the double-projection Kelsh instruments.

In Pennsylvania, photographic targets will be set before photography on all future highway surveying projects where photogrammetric instruments will be used. Photographic targets save time and money and improve accuracy through certainty of correlation between ground positions, photographic details in the stereoscopic models, and positions on the maps.

i. Charles Pinnell gave his report on research which will soon be undertaken at the Texas Transportation Institute. Traffic surveys will be made using aerial photography. Fixed-position use of a movie camera on a pole has not given all data desired. There is a lack of data regarding vehicle movements before entering and after leaving a particular section of highway. The traffic survey research will be conducted along a 6-mi section of freeway. Possibly two aircraft will be employed for taking continuous-strip photography during peak hours of traffic. The aerial photographs will be taken at frequent intervals of time and used to ascertain vehicle speeds, spacings, and numbers.

(1) Mr. Anschutz said the continuous-strip aerial camera should be installed in a fast-flying aircraft which should be flown close to the ground. Movement of the aerial film in the camera at a speed synchronized with the ground speed of the aircraft is essential and easily achieved.

(2) Mr. Pryor said Gordon Enterprises, 5362 North Cahuenga Blvd., North Hollywood, Calif., may have a stock of continuous-strip printers and stereoscopic viewers. Recently, LogEtronics, Inc., 500 East Monroe Ave., Alexandria, Va., placed a new automatic dodging continuous-strip printer on the market.

j. Mr. Herd gave a report on highlights of current events in aerial surveys in Ohio. Eleven people from different highway construction districts of the State were given instruction in the operation of precision photogrammetric instruments.

Since construction engineers have been given this training, their new insights have resulted in more effective uses of aerial surveys, and their confidence has been increased in surveys. Now construction engineers are having a voice in planning, surveys, and designs, and in the photogrammetric measurement of cross-sections for design and computation of construction pay quantities on Federal-aid projects.

Ohio continues to have many surveys and designs done by consultants who employ photogrammetric engineering firms to take the aerial photographs, to make the essential ground control surveys, to compile the maps, and to measure profiles and cross-sections. Then the consultants use the survey data in designing the highway locations and preparing detailed construction plans.

Cross-sections are measured photogrammetrically on highway construction projects at the stations and plus points where cross-sections were previously staked for construction and were measured and used during design. Construction pay quantities are computed by using the pre-construction and post-construction cross-sections, as modified for payment by the project construction engineers.

The Ohio Department of Highways has eight Kelsh stereoscopic plotters using 8.5-in. focal length photography on a three-shift basis each working day. A Bell helicopter is used for oblique photography, because good well-positioned obliques were seldom obtained from a fixed wing aircraft. A Fairchild 500 aerial camera is used for most mapping photography. Many other cameras are available for special purposes. The photographic laboratory has two LogEtronic automatic dodging printers. A Wild Pug 2 device is used for marking of pass points. Glass plates from the Eastman Kodak Co. have been of better quality than plates obtained from another firm on a recoated basis.

Ohio now uses a 7070 electronic computer for numerous types of computations required in conjunction with ground surveying, photogrammetric operations, highway design, and procurement of rights-of-way as well as computation of construction quantities. Correlation of photogrammetric operations with electronic computations has greatly increased the benefits of both photogrammetry and electronic computers to highway engineering in Ohio. Analytical photogrammetry is contemplated as soon as economically feasible.

k. Mr. Shelby reported revision of the Photogrammetry Manual of the Texas Highway Department is nearly complete. This manual contains eight sections: first, a definition of terms; second, preface containing the purpose of the manual, the importance of horizontal and vertical control, the significance of aerial photographs and maps compiled by photogrammetric methods, and procedure; third, the classes of surveys undertaken, aided by photogrammetric techniques of using aerial photographs; fourth, step-by-step procedure engineers of each district in the highway department should follow in obtaining the services of the photogrammetry section; and fifth through seventh, samples of procedures and specifications for procurement by contract of aerial photography, photographic mosaics, and photogrammetrically compiled maps. The eighth section contains standard specifications for aerial surveys and mapping by photogrammetric methods as revised in 1960. These specifications follow the two divisions of the Reference Guide Outline (See Sect. 6, Minutes of 12th Meeting). A second manual has been prepared by the Highway Design Division of the Texas Highway Department on the use of maps compiled by photogrammetric methods.

Uses of aerial surveys are on the increase throughout Texas. About 60 percent of the photogrammetric work is done by State forces and equipment and the remainder by contract. This year, highway engineers in Texas began using the electronic distance measuring Electrotape. On one distance of 2,300 ft, difference was only 0.06 ft, or less than 1:38,000. The Electrotape operates best at ¼ mi and longer distances. The units now used by Texas will be modified for accurate measurement of distances of less than 500 ft.

Texas has had good success within metropolitan areas in using maps and measurements made by photogrammetric methods for rights-of-way plats and for procurement of right-of-way parcels. Pay quantities have not yet been computed in Texas by use of photogrammetrically made measurements.

Photogrammetrically made surveys close mathematically, wherever plane coordinates are used. The photogrammetrically measured points and points of closure computed from plane coordinates can be staked on the ground beginning from points of the basic control on the survey project.

Acceptance and use of aerial surveys has been increasing steadily since the modest beginning several years ago. Varying differences of opinion regarding uses and benefits to be gained from aerial surveys in the successive stages of highway engineering are being reconciled. About 70 percent of the present utilization of aerial surveys in Texas is by six or seven of the 26 districts. Some districts prevent seasonal employment problems by assigning construction engineering personnel to highway surveys when construction projects are closed down due to bad weather.

l. The report mailed to the Committee by Irwin Sternberg, District Location Engineer, Arizona Highway Department, was read by Mr. Futrell. During the past year the Photogrammetric Division of the Arizona Highway Department completed some 440 mi of both topographic and planimetric mapping to scales ranging from 50 ft per in. with a 2-ft contour interval to 400 ft per in. with a 10-ft contour interval. Assemblies of uncontrolled and semi-controlled photographic mosaics have been completed to various scales for about 180 mi.

As an experiment, the designed location has been fixed on the ground; that is, PI's have been set from control points and measurements have been made at ¼- to ½-mi intervals with the two Geodimeters. This is believed unnecessary because field crews should have enough information on maps compiled photogrammetrically by use of adequate control to set their own location control points as the centerline is staked. Accuracy of tape-measured lines can also be checked easily by making ties to markers of permanent control points by use of plane coordinates.

So far there has not been much interest shown in the use of automatic cross-section measurement and recording devices. There seems to be a preference for scaling cross-sections directly from the contours of the larger scale topographic maps. There is also a preference among plotter operators for the three-projector Kelsh stereoscopic plotter because set-up time for the second model is reduced, vertical control troubles can be isolated more easily, bridging is possible, and the instrument has greater Y and Z motions.

A six-projector Balplex aerial triangulation instrument is used to establish supplemental control for map compilation with the Kelsh stereoscopic plotters. The Balplex is also used as two three-projector compilation instruments and seems to be ideal for planimetric strip mapping used for location purposes and for compilation of planimetric maps on a county basis.

Practically all field work being done for the mapping projects is based on the spacing requirements for a photogrammetric bridge of five stereoscopic models. This means a substantial reduction in horizontal control work, which of course leads to a much more economical mapping program. The bridging with the Balplex instrument follows pretty much the same techniques as those used with the multiplex aeroprojectors. Accuracy of the supplemental control points determined through a bridge of five stereoscopic models is increased considerably by placing targets on the ground and on line between primary control points surveyed on the ground. Some Cronar and Estar base aerial film, as well as infrared film, is being used.

m. L. W. Verner gave a brief report of aerial surveys in Georgia. All aerial survey work is now done by State forces and equipment. A 6-in. focal length Wild aerial camera, operated at shutter speeds of 1/300 and 1/200 sec, is generally used. A 12-in. focal length aerial camera is used for taking illustrative aerial oblique photographs. An Aero Commander, 2-engine, aircraft is used on all aerial photography missions. Four two-projector Kelsh stereoscopic plotters are in operation on a full-time basis during each working day and are used during evenings, by cooperative arrangements, for instrument operation training of students by the Georgia Institute of Technology.

Topographic mapping by photogrammetric methods has been completed for more than 1,000 highway survey miles. Most of this mapping has been done at the scale of 100 ft to 1 in., with a contour interval of 2 ft, and some at the scale of 50 ft to 1 in. with a contour interval of 1 ft. Cross-sections for design have been measured from the maps after establishment of the centerline. In establishing basic control for the highway survey projects, Tellurometer units are used with Wild T-2 theodolites.

Georgia has a 2-yr training program for engineers in all phases of aerial surveys and photogrammetry. Basic principles, photogrammetric instrument operation, and ground control surveying are given. This training is available to the engineering students of the Georgia Institute of Technology.

n. Mr. Winsor spoke regarding the work of five regions of the U. S. Bureau of Public Roads where engineering surveys and design, and supervision of construction are done by Federal employees for highways to and within the National Forests and

Parks and for other highways financed wholly with Federal funds. All of such work is supervised by the Federal Highway Projects Division in the Office of Operations.

Region 9 has an Electrotape, but both 10- and 12-ft subtense bars are used in making short distance measurements with a theodolite, as the Electrotape has not been suitable for measuring such distances in ground control surveying. The region is beginning to use color separation in the printing of plan and profile sheets. Topographic maps at the compilation scale of 100 ft to 1 in. are used; however, the printing is done at the scale of 200 ft to 1 in.

A tape-actuated typewriter containing engineering symbols is used for typing names, numbers, and symbols on transparent material. These are then placed on the plan and profile sheets with an adhesive, resulting in uniformity in lettering and placement. Five separate plates are scribed on scale stable polyester sheets. Each plate contains a separate class of information, which is printed on the reduced size plan and profile sheets as follows: Highway alignment and grade lines in black, drainage and water in blue, trees and other tall dense vegetation of significance in green, contours and ground profile in brown, and right-of-way lines in red. The cost is $0.06 per sheet which is slightly more than the cost per sheet for regular offset printing in black and white. But the use benefits of having significant details separated by color justify the expenditure, as proven by use on several highway construction projects.

(1) Mr. Higginson said the U. S. Geological Survey changed in 1954 from drafting to scribing. The map details are delineated on the scribe coated, scale stable, polyester sheets by graphite pencil by the instrument operator as he compiles the map by movement of the tracing table over the stereoscopic model. The map scribing is then done by the same person using a scribing tool. Each map detail is scribed where delineated by the photogrammetric instrument operator. A photographic print is then made from each scribed map sheet. Using this copy as a guide, an expert scribing tool user scribes several different sheets, each containing details to be printed in a separate color on the finished map.

(2) Mr. Katibah said a new scribing method had been developed by Keuffel and Esser eliminating any need for a light table.

(3) Mr. Higginson said each separate final sheet is registered in an exact position with respect to each other sheet of the set by use of studs in registration holes punched before scribing was done.

(4) Mr. Katibah remarked there is emulsion creep on large polyester sheets, but this creep would probably not cause much difficulty on the 11- by 16-in. sheets used in Region 9.

(5) Mr. Shelby asked what Mr. Winsor meant by distances too short for the Electrotape to measure. Mr. Winsor answered 500 to 800 ft. Region 9 engineers had not achieved good results in their efforts to measure distances of less than 800 ft with the Electrotape. Mr. Shelby said the Electrotape has a three-degree measurement field, and the Tellurometer has a much larger field.

9. Mr. Wright reported on work done by Lockwood, Kessler, and Bartlett, Inc., 1 Aerial Way, Syosset, L.I., N. Y. In precision surveying for highway design, all profiles and cross-sections are measured in the optical train precision photogrammetric instruments. The instruments used are the Wild Autograph Model A5, the Galileo-Santoni Stereosimplex Model 3 and Stereocartograph Model 4. The Stereosimplex Model 3 uses single stereoscopic models (as does the Wild Autograph Model A8), but the Stereocartograph Model 4 is a universal instrument (like the Wild Autograph Models A7 and A5 and the Stereoplanigraph Model C8) in which either aerial vertical or oblique photographs can be used.

Lockwood, Kessler, and Bartlett also has a large precision coordinatograph and a CDC 160-A (Control Data Corp.) electronic computer. The Geodimeter and Tellurometer are used in basic control surveying; the Geodimeter is considered the most accurate. The Wild RC-5 aerial camera is used for most of the aerial photography. The Galileo-Santoni Stereocartograph Model 4 and the Wild Autograph Model A5 are preferred for measurement and automatic recording of profile and cross-sections. The Stereosimplex Model 3 is not equipped with auxiliary equipment for digital recording of profile and cross-section measurements. The firm also has seven double-projection Kelsh instruments. The CDC 160-A electronic computer rents for $2,500/mo. The purchase prices of the Galileo-Santoni instruments are $35,000 and $70,000 for the Stereosimplex Model 3 and the Stereocartograph Model 4, respectively.

10. Harl Pugh of R. M. Towill, Inc., 612 Howard St., San Francisco, Calif., described the photographic contour map, a development of the Corporation. The photographic contour map is the same as the standard topographic map with respect to contours representing the configuration and elevation of the ground, but planimetry, is not delineated. Instead, an orthophotograph is printed successively between each pair of contours.

Either vertical or 16° convergent photography is used in compiling the contours. Only vertical photographs are used to print the orthophotograph. A pendulum-mounted single lens aerial camera with 8¼-in. focal length is used take the convergent photographs. As the aircraft is flown along the photography flight line, the camera is swung successively from the forward oblique to the vertical to the back oblique photography positions, and then the cycle is repeated until all convergent oblique and vertical photographs are taken along each flight line of the survey project.

The contours are measured and delineated from the stereoscopic models formed from the convergent photography projected at the ratio of 4:1. Using a graphite pencil in the tracing table of a Kelsh stereoscopic plotter, the contours are scribed onto a scribe coated sheet, and a translucent line positive is made of each map on a polyester base film. The vertical photographs are oriented to control and the map manuscript containing the contours, is oriented with the stereoscopic model on the mapping surface of the Kelsh instrument. A scale stable film containing a photographic emulsion is placed on the mapping surface of the Kelsh instrument and underneath the translucent sheet containing the contours. Each contour level is stripped out (as between contours 105 and 110, contours 110 and 115, and so on) and an exposure is made of each strip, until the entire negative has been exposed. Before each band of topography is exposed, however, the working surface of the Kelsh instrument is raised, at the mapping scale, to the mean elevation of the contours between which the exposure is to be made. The exposure is accomplished by turning on the light from only one of the projectors of the Kelsh instrument. A halftone negative is made of the map and the contours are superimposed on the orthophotograph. Prints are made from the halftone negative by any of the printing processes, such as blue printing. In making the negative, the photographic contour map is enlarged from 4 times to 5 or 6 times the photography scale to achieve the scale desired in the map by the users.

a. Mr. Katibah remarked the photographic contour map is very effective for display and demonstration purposes at public hearings, for evaluation and negotiation of rights-of-way, and for highway design.

b. Mr. Pugh said the best combinations in preparation of the photographic contour maps are 100 ft to 1 in. with a 5-ft contour interval, and 200 ft to 1 in. with a 10-ft contour interval. The midpoints between contours are exact. Image displacement for one-half contour interval is less than accuracy of planimetric details on planimetric and topographic maps.

c. Mr. McNoldy commented Pennsylvania has highway survey projects where the photographic contour map would be ideal. A photogrammetric engineering firm on the east coast which prepares the photographic contour map is Aero Service Corp., 210 E. Courtland Street, Philadelphia 20, Pa.

d. Mr. Pugh said success in use of the photographic contour maps has been achieved because of the ease with which nearly all people who are not engineers understand them. The R. M. Towill Corp. began making the photographic contour maps in 1947. Their engineering uses became secure when scale stable polyester bases became available for making them.

e. Mr. Funk commented costs of compiling and using photographic mosaics and topographic maps separately in lieu of photographic contour maps are about equal. The advantage of the photographic contour map is in having photographic images more replete with details than the planimetry on topographic maps and in having the contours together on the same sheets.

g. Mr. Pugh said the cost of photographic contour maps is $1.00/acre at the scale of 200 ft to 1 in. with a contour interval of 10 ft. A better way in which to estimate the costs of these maps is on the basis of $1,000 per stereoscopic model. This costs includes the photography, ground control surveys, and use of the photography and ground control to measure and delineate the contours, print the orthophotograph, prepare the halftone negatives, and make a set of prints of the finished photographic contour maps.

The photographic contour maps may be used in highway design, and the designed centerline and alignment data can be placed on the original negative for printing highway plans by use of an overlay. Then the added data are "halo" printed so they will show clearly on the initially prepared photographic contour map.

11. Mr. Nielsen read the progress report of Clyde T. Sullivan, of June 1962, on the cooperative project with the Virginia Department of Highways, as follows:

Approximately 2 yr ago, the Forest Service presented an interim report on a project undertaken in cooperation with the Virginia Department of Highways. It was reported at that time results were inconclusive and additional tests were planned, which involved procurement and use of new photography at scales of 350, 700, 1,050, and 1,400 ft to 1 in. with image and target control. This involved establishment of new control points and placement of photographic targets on the ground before aerial photography by the Virginia Department of Highways and the U. S. Bureau of Public Roads. Aerial photography was procured by the Virginia Department of Highways through use of its own Wild camera equipped with a $\frac{1}{300}$ sec shutter and through contract with Aero Service Corp. using a Zeiss camera equipped with a $\frac{1}{1,000}$ sec shutter. The U. S. Forest Service has completed the measurement and computation of a large number of Stereoplanigraph Model C8 photogrammetric bridges.

These photogrammetric bridges use each of the four scales of aerial photographs taken with each of the two cameras. In addition, these were measured using control with and without photographic targets on every fourth stereoscopic model, and every fourth stereoscopic model plus highway centerline control spaced at an interval of approximately 1,400 ft. Based on the computation of about 40 bridges it was concluded that horizontal accuracy is greater when targets are used in preference to image points. This is not directly proportional to the flight height. The average error with targets for flight heights of 4,200, 6,300, and 8,400 ft were 1.08, 1.44, and 1.85 ft, respectively. However, targets do not consistently give a greater vertical accuracy in preference to image points. Horizontal and vertical accuracies, using targets and image points, were increased when highway centerline control spaced at an interval of approximately 1,400 ft was added to the control on every fourth stereoscopic model. The increase in accuracy is not directly proportional to the amount of control added; approximately 8 times the amount of control on photography at a scale of 700 ft to 1 in. reduced the horizontal error approximately one-third.

The Wild and Zeiss cameras are equipped not only with shutters of different speeds but also with lenses of different resolution characteristics. Tests show resolution characteristics of the lens in the Wild camera are superior to those in the Zeiss camera. This tends to counteract the effect of computable aircraft movement; therefore, the amount of error attributable to aircraft movement during exposure time could not be definitely determined.

It was planned to undertake tests to determine if control established photogrammetrically from small-scale photography would be suitable for use in controlling large-scale design photography. A comparison has been made of results obtained on identical image points of the four scales of photography. Accepting measurements made with photography at the scale of 350 ft to 1 in. as correct, it was found that 90 percent of the targeted points on photography at the scale of 1,400, 1,050, and 700 ft to 1 in. agreed horizontally within 3.3, 2.7, and 2.0 ft, respectively, and vertically within 2.6, 2.0, and 1.1 ft, respectively.

Photogrammetry is sometimes oversold. There are circumstances where expectations cannot be fulfilled. Thus far the greatest successes achieved in uses of photogrammetry by the U. S. Forest Service have been in small-scale mapping for reconnaissance survey purposes.

a. Mr. Higginson stated that, in his consultant engineering work, he had enlarged 1:24,000-scale maps as much as 5 times to 1:4,800. These enlargements, when the original compilations were by photogrammetric methods, served very well.

b. Mr. Katibah said 1:48,000-scale vertical photography can be used for reconnaissance.

c. Mr. Funk suggested it is best to get new photography taken to specifications which will assure use of a precision aerial camera of proper focal length, good resolution, and negligible distortions. Then, existing control can be used. Reconnaissance-type mapping will require little, if any, additional field-surveyed control. In most cases, needed supplemental control can be bridged with precision photogrammetric instruments.

d. Mr. Higginson said existing photography taken with the T-12 aerial camera is usually good for reconnaissance-type mapping, but photography taken with a metrogon lens aerial camera may cause some difficulties.

e. Mr. Futrell remarked that in Washington the farm-to-market roads are located, in many cases, by use of aerial photographs only. Parallax is measured to determine differences in elevation and to ascertain location gradients as the highway route is located and delineated on the aerial photographs. Then the highway is staked directly from the photographs to the ground for construction. These methods serve well for the location of roads not requiring alignment and gradients essential for large numbers of vehicles traveling at high speeds, and are similar in detail to those developed and recommended by the U. S. Bureau of Public Roads for locating feasible route alternatives for highways.

12. Mr. Higginson asked which thicknesses of glass plates are used by highway departments. His question pertained to use in both double-projection, and optical train photogrammetric instruments, and glass plates of 0.25, 0.125, or 0.06 in. thickness. This question also extended into practice where specifications were written for the obtainment of maps by contract from photogrammetric engineering firms.

a. Mr. Katibah said California desires plates of 0.25 in. thickness but will permit use of plates 0.125 in. thick. Use of plates of 0.06 in. thickness is not permitted because sag has been proven from tests. Mathematically, it has also been proven glass plates of 0.06 in. thickness sag enough to cause warping in the stereoscopic models formed by projection of the photographs printed on such plates when used in double-projection instruments.

b. Mr. Shelby said Texas had found plates of 0.125 in. thickness are not optically true.

c. Mr. Katibah continued by saying center supports are not used with the instrument projection cones in California.

d. Mr. Anschutz also said center supports are not used on the double-projection instruments in Kansas.

13. Mr. Pryor remarked it is difficult to separate practice and new achievements attained while the usual survey work is done, whether accomplished in the routine manner with which most engineers are familiar or in some way different from the usual. Moreover, what may be routine in one State may be entirely new to another. Exchanging ideas, giving factual reports on practice and results in relation to circumstances and conditions, and reporting successes and other results from any State may be exactly the information pertinent to assisting another State in solving its current problems.

13TH MEETING, JANUARY 7 AND 8, 1963
(Washington, D. C.)

1. Chairman Glenn Anschutz called the Committee to order.

2. The Committee was congratulated by F. N. Wray, Highway Research Board, for its new Chairman, Glenn Anschutz, and for the large amount of excellent work done, especially for the Aerial Surveys Program arranged for the 42nd Annual Meeting of the Highway Research Board. Mr. Wray reviewed past contributions of the Committee to Highway Research Board meetings. (See HRB Bull. 157 (1957), 199 (1958), 213 (1958), 228 (1959), 258 and 283 (1960), 312 (1961), and 354 (1962; also HRB Correlation Serv. Circ. 412 (Feb. 1960), 428 (Sept. 1960), 463 (Feb. 1962), and 480 (Sept. 1962)).

3. W. Richard McCasland, Texas Transportation Institute, Texas A&M College, made a brief report regarding the traffic survey being conducted for a 6-mi segment of the Gulf Freeway at Houston, Texas. He displayed 9- by 18-in. photographs taken at a scale of 100 ft to 1 in. and providing nearly 1,000-ft width of coverage of the freeway and adjacent lands. Stereoscopic, continuous-strip photographs were also taken of the 6-mi section at the scale of 250 ft to 1 in.

Traffic movement characteristics, density, and speed were ascertained from the photographs. Vehicle counts were also made on the ground. Marked vehicles were continuously moving on the freeway section during the period when aerial photographs were being taken. Correlation checks of aircraft flight direction and speed were made with travel speed of the marked vehicles at designated intervals of time while the aerial photographs were being taken.

It is not possible to ascertain the traffic movement pattern along a 6-mi segment of a freeway from vehicle counts made at one or two places only. The aerial photographs, however, contained an image record of each vehicle at easily determined time intervals from which vehicle movements on the freeway, interchange ramps, and frontage roads could be easily ascertained. Obtainment of such data at the peak hour of traffic density by these methods became especially significant. The congestion zones and causes of slowdowns and tie-ups were easily recognized by examination of the photographs.

The marked vehicles were the key to identification, just as a photographic target makes it possible to pinpoint the survey control station marker over which it is centered when aerial photographs are used in photogrammetric instruments for precision mapping. Speed measurements made from the aerial photographs, when correlated with the marked vehicles for which the exact speed is noted at the predetermined interval of time, gave results agreeing within 3 to 4 mph. These speed determinations are within 10 percent of the speed of vehicles on the freeway.

The effects of trucks on traffic will probably be ascertained, as will all other traffic influencing factors.

a. Thomas D. Jordan of the Port of New York Authority, remarked the ground speed of the photographic aircraft must be accounted for in determining the speed of motor vehicles from continuous-strip photographs. Whether or not the aircraft is flying in the same direction as the vehicles is vital in using parallax measurements on continuous-strip photographs.

b. Mr. McCasland informed the Committee that traffic density zones are plotted using data obtained from the photographs. The zones are identified by their extent and by the number of vehicles within them, represented by vehicles per traffic lane mile.

Eleven photographic flights were made each day for 2 days over the 6-mi segment by one photographic crew using the Sonne continuous-strip camera at a cost of $2,500/day; nine flights were made on one day only by another crew using the camera taking single exposure 9- by 18-in. photographs at a cost of $2,500/day.

4. Frederick A. Wagner, Jr., of Thompson-Ramo-Wooldridge, Inc., gave a summary of the paper he and Adolph D. May, Jr., had prepared on "The Use of Aerial Photography in Freeway Traffic Operations Studies."

The hand-operated aerial camera with which 5- by 5-in. photographs were taken proved practicable for taking aerial photographs of traffic. Such photographs were used to ascertain traffic parameters of density (vehicles per lane) using easily recognized ground reference points between ¼ to ½ mi apart to differentiate contiguous highway sections and counting the vehicles within the bounds of each section. A 7-mi segment of freeway was included in the traffic survey and study. The aerial photographs were used to ascertain traffic demands—the number of vehicles which were endeavoring to move (not number actually moving) through a bottleneck. A fixed wing aircraft at the flight height of 6,000 ft was usually used. A helicopter was used occasionally to make aerial observations. The camera used had a 7-in. focal length.

5. Joseph F. Rice, District of Columbia Department of Highways and Traffic, gave a summary of his paper on "Adoption of Aerial Survey Methods for Traffic Operations." Photographs used are taken from flight heights between 200 and 2,000 ft, according to scale and details desired. Unbalanced traffic conditions are easily seen on aerial photographs. A helicopter was used to fly from one zone of traffic congestion to another. In this way, it was possible to take aerial photographs from which the causes of traffic congestion (accident, congestion, and interference at intersections and places of merging and turning vehicles) could be determined.

Traffic speed, number of vehicles, and density are the parameters obtained from stereoscopic triplets of aerial photographs taken at 10-sec intervals along each highway segment. The interaction of traffic from one bridge to another and from one segment of major egress and ingress to another was studied. A 10 percent sample gives usually adequate results.

a. John O. Eichler asked whether or not driving to a parking area on the perimeter of a metropolitan area and then using bus transportation into the city to one's destination would be effective and accepted by the commuter.

b. Mr. Jordan said in New York, people are accepting and using the parking-commuter terminals.

Electronic computers will determine vehicle speed from parallax measurements made on single exposure pairs of aerial photographs as 9- by 9-in. negatives or contact prints from the negatives. Parallax measurements are made by relating ground position and vehicle position on the successively taken photographs of 600 and 900 ft to 1 in. scales.

c. James H. McLerran, Photographic Interpretation Research Division, U. S. Army, Corps of Engineers, remarked that a thermal sensor will soon be available for night photography. This device was developed for the Department of Defense for photographic interpretation purposes. It is not fog penetrating but gets good results under clouds and at night. It is expected that by use of this device traffic engineers will be able to get a photographic record of traffic during peak hours in winter before sunup and after sundown.

6. Thomas N. Tamburri, California Division of Highways, gave a summary of his paper, "California's Aerial Photography Inventory of Freeways." Vertical photographs of 9- by 18-in. size (12-in. focal length, scale of 200 ft to 1 in.) were taken with long dimension parallel with the aircraft line of flight. An overlap of about 15 percent was obtained. The photographs were used to make inventory surveys of freeways and their interchange ramps, of parking, and of traffic control devices; to identify adjacent properties; to demonstrate proposed improvements at public hearings; to ascertain changes in land use adjacent to new highways; to get an extension of data beyond details on construction plans where necessary; to study the circumstances and conditions incident with occurrences of wrong-way driving; to study the relationship between highway accident rates and highway geometrics; and to make analyses of the sites where accidents occurred.

7. Joe V. Evans, State Highway Department of Georgia, gave a summary of his preliminary report, coauthored by Peter Malphurs, on vertical and horizontal bridging with the Kelsh stereoscopic plotter. The techniques were developed to reduce the cost of field surveying for establishing supplemental control. For example, trigonometric leveling had not been proven to be adequate because vertical angles could not be measured to sufficient accuracy. Techniques used indicate bridging of horizontal control

can be achieved to requisite accuracy. Bridging of vertical control, however, needs improvement. In the bridging work done, 4, 5, and 7 stereoscopic models have been used in one bridge using vertical photography at scales of 250, 500, and 1,000 ft to 1 in.

8. Mr. Anschutz gave a brief summary of the paper written by Alvis H. Stallard and himself on utilizing the Kelsh stereoscopic plotter in geo-engineering and allied investigations in Kansas. Targets of suitable size and symmetrical shape are placed before photography on markers of basic control, supplemental control, and any other points or features for which positive identification and/or measurement are desired, such as geologic structures, seepage, slides, migrating streams, property corners and lines, and sites of construction materials. The determination and comparison of several alternatives are essential to achieve best results in the solution of highway engineering problems. Aerial surveys are especially adaptable to such procedure. When aerial surveys are used, it is possible for each member of the highway engineering team to review the problems, their proposed solutions, and make recommendations based on the pertinent facts. Moreover, whenever a question arises, the source data are immediately available for detailed review, as necessary, to support the decisions.

9. Harold Rib said several States are now doing research in use of photographic interpretation, especially to accomplish soils mapping and to locate sources of construction materials. Such work has the approval of the Washington office of the U. S. Bureau of Public Roads.

10. Robert D. Miles remarked there is a controlled photogrammetric experiment being conducted under sponsorship of Working Group 4 (Civil Engineering), Commission IV (Mapping from Photographs), International Society for Photogrammetry. This experiment has been planned to ascertain specifically what accuracies can be achieved in making measurements for highway engineering purposes by photogrammetric methods.

a. Mr. Pryor explained that as the U. S. A. member of Working Group 4, he had informed highway departments with precision photogrammetric instruments of the experiment. All but one of these States have applied for participation.

b. Results of the experiment will be presented at the Tenth Congress of the International Society for Photogrammetry, which will be held in Lisbon, Portugal, September 6-19, 1964.

11. Mr. Anschutz said data regarding the use and performance of the Electrotape are desirable. There is need for comparison of the effectiveness and efficiency of the Electrotape with the Geodimeter and Tellurometer.

a. Marshall S. Wright remarked the newness of the Electrotape makes dissemination of information regarding its performance of interest and benefit to everyone engaged in the utilization of electronic measuring instruments. Texas is the first State to purchase and use the Electrotape.

b. George P. Katibah stated the California Division of Highways is converting eight State-owned Geodimeters from night to day operation. The Geodimeter Model 4D will be available in February 1963 and will cost more than $8,000. It will measure distances to about 3 mi in daylight and to 15 to 20 mi in darkness within ± 0.04 ft.

12. Based on remarks of several committee members, consensus was that measurements of profile and cross-sections made by photogrammetric methods are often a test of the accuracy of profile and cross-sections measured by the usual survey methods on the ground, rather than vice versa.

Lloyd O. Herd, Ohio Department of Highways, said the Ohio Department of Highways measures all grading quantities by photogrammetric methods. The procedure is to photograph the highway route for mapping and making such other measurements as necessary for design of the location and preparation of detailed construction plans. The highway route is then photographed again after the centerline of the designed highway has been staked on the ground for checking the construction plans. This is done before construction is started. When the highway construction is completed, another set of aerial photographs of appropriate scale are taken and used to photogrammetrically measure the highway as constructed. Differences between the measurements made before and after construction are a measure of the earthwork quantities moved in constructing the highway.

13. Mr. Pryor gave some examples of the frequent improper use of words, such as: naming a map by its method of compilation, as photogrammetric map, instead of its proper name as topographic or planimetric, depending on whether the third dimension and configurations of the ground are delineated by contours or in some other manner; indiscriminate use of the abbreviation "photo" for photograph, photography, photographic, photographing, such as for photography index or photographic mosaic; using altitude instead of flight height, when the intent is to express the height above mean elevation of the ground from which the aerial photography negatives were exposed (flight height is the mean elevation of the ground subtracted from the altitude at which the aircraft is being flow).

a. As an example of nomenclature, Mr. Pryor gave a definition for aerial surveys in highway engineering, which is the taking and use of aerial photography to obtain whatever is required, both qualitatively and quantitatively, while the engineering work is being done. Use of the aerial photography can be by photographic interpretation, by photogrammetric methods, or by illustrative techniques or any combination thereof according to purpose or need.

b. Charles Pinnell said a glossary will serve many purposes beyond aerial surveys for highway engineering purposes, thereby making papers on the subject more useful to a larger number of readers.

c. Charles E. McNoldy commented such a glossary would be useful to men primarily engaged in aerial photography, in making ground control surveys, and in using photogrammetry and photographic interpretation when they are discussing their work with the highway engineers they are engaged to serve.

d. M. D. Shelby said the Committee was considering an important subject, because there is an increasing need to get the proper terms well established, understood, and used in the same manner by everyone.

e. Mr. Anschutz suggested each member of the Committee compile a list of terms needing definition for discussion at the July 1963 meeting. Everyone should make a contribution because practice and use sometimes vary from region to region and from State to State.

f. Mr. Shelby said the legal aspects of terms and their use in deeds and courts must also be considered.

14TH MEETING, JULY 15-17, 1963
(Jekyll Island, Ga.)

1. Franklin N. Wray, Highway Research Board, mentioned the participation of William T. Pryor in the 9th Pan American Highway Congress and the citation given to him for the paper he presented on "Evaluation of Aerial Photography and Mapping in Highway Development." The Congress unanimously passed a resolution that the paper should be translated into all other official languages of the Congress—French, Portuguese, and Spanish—and distributed to all member countries.

2. Committee Chairman Glenn Anschutz initiated discussion of a glossary of terms. He emphasized the desirability of uniformity in use of words in the photogrammetric field, particularly in utilizations for highway engineering purposes.

a. Marshall S. Wright, Jr., mentioned the American Society of Photogrammetry has a nomenclature committee. This committee prepared Chapter XIX on "Definition of Terms Used In Photogrammetry," which was published in the Manual of Photogrammetry by the Society in 1952. In the revised edition of the manual, which is being prepared, a chapter containing definitions of terms will also be included.

b. Mr. Pryor remarked Chapter XXIV of the revised Manual of Photogrammetry, the third edition of this manual, will contain definitions of terms strictly photogrammetric in character and may not be especially applicable to utilization of aerial surveys for highway engineering purposes. The glossary of terms which the P&AS Committee should prepare ought to contain words directly related to highway engineering work. Users of the glossary prepared by the P&AS Committee should not, however, be required to go to another glossary. Whenever possible, ASP terms and definitions should be used and the source appropriately indicated in order to make a complete glossary.

c. Mr. Wray said a glossary of terms prepared by the P&AS Committee could be published as a supplement to the definitions of terms prepared by the American Society of Photogrammetry. In so doing, the work of the P&AS Committee would not be a duplication of the work done by the nomenclature committee of the American Society of Photogrammetry nor would the publication be considered out of order. People who are not engaged in highway engineering utilizations of aerial surveys would have difficulty in understanding all aspects of papers regarding such activities without access to an appropriate glossary. The P&AS Committee does have the responsibility of endeavoring to obtain unified use of pertinent words.

d. Mr. Anschutz said one of the significant uses of the glossary would be by authors of papers and by editors.

e. John O. Eichler said a glossary of terms must be prepared primarily to reduce misunderstandings and to achieve conciliations. Actually, a glossary of terms has the purpose of unification. If a word is worth defining, whether or not it has been defined elsewhere, it should be included in the glossary.

f. Clyde T. Sullivan said it would be necessary to become fully aware of all of the terms in photography, photogrammetry, control surveying, and highway engineering. Such a broad field of application indicates the possible need for a manual rather than a glossary.

g. Mr. Pryor said agreement among highway engineers, as well as among other people, on use of words is necessary if misunderstandings are to be avoided. Unfortunately, variations result from differences in individuals and regions and occur from one occasion to another among the various users of each significant word according to the intent in its use. Differences exist between concepts of photogrammetric engineers and highway engineers. Some highway engineers think and speak of aerial photographs as maps. In actuality they are not maps but perspective projections made at an instant onto a plane. Also, some highway engineers think of relief displacement and tilt displacement of images on photographs as lens distortions. Actually, aerial photographs taken with a "distortion-free" camera contain the perspective displacement of images caused by ground relief, whether or not the photographs are truly vertical or tilted. When tilted, the consequences of tilt-caused image displacements are additive to and subtractive from relief displacements, depending on the direction of tilt.

3. Herbert L. Brantley gave the highlights of his proposed paper on use of electronic distance measuring devices in Illinois. It pertains to a highway location project for which the route corridor, about 2,200 ft wide, had been mapped photogrammetrically. The firm engaged by contract to do the mapping did not use photographic targets. Field survey tests proved the maps to be insufficiently accurate. Part of the map testing, of course, occurred during staking of the designed centerline on the ground which was done as accurately as the basic control had been established for the mapping. Test results, in addition to the centerline staking and profile measuring, further substantiated there had been lack of correlation by the mapping contractor between control points and photographic images, and nonuse of photographic targets was a contributing factor. Consequently, the separate stereoscopic models were not always oriented properly in relation to the control nor were they adequately scaled to control.

Tests were undertaken on another project for which surveys had to be made to design the location and prepare construction plans. The photographic targets were set on the ground at an interval of approximately 400 ft along the base traverse and in the corners of each stereoscopic model. It was intended the base traverse would not be more than 300 ft laterally from the center of the corridor of the proposed highway route. The photogrammetric firm engaged to compile the maps for this survey and design project, however, followed the line of least resistance when staking and measuring to avoid trees and brush and other obstacles on the ground. Consequently, the base traverse ranged from the desired maximum of 300 ft to more than 500 ft from the proposed position of the centerline.

After the preliminary survey maps had been photogrammetrically compiled and the highway design completed, desirable positioning of the centerline placed it somewhat farther from the center of the highway route corridor than 300 ft. This resulted in the designed centerline actually being less than 300 ft from the control survey base traverse. The designed centerline was staked on the ground by measuring from the targeted points on this traverse. The position of the designed centerline was then accuracy tested by a Tellurometer. Results achieved were good. Both the centerline staking and the Tellurometer checking revealed errors were made in the base traverse by the photogrammetric engineering firm. These errors occurred because sufficient ties were not made from the base control traverse to control points previously established by the U. S. Coast and Geodetic Survey near the highway route. Consequently, orientation of stereoscopic models to inaccurate control, despite the fact stereoscopic correspondence of photographic images had to be forced to warp each model to such control, resulted in maps which were not accurate.

Test of the maps on a spot elevation basis showed that they had been well compiled. Relative differences between true horizontal position and elevation would have been slight had the maps not been displaced from proper coordinate position to fit inaccurate control. Further investigations revealed the photogrammetric instrument operators had made transpositions in forcing stereoscopic models to the inaccurate basic and supplemental control; e.g., an elevation of 601 had been used for one of 610. On an over-all basis within local areas, after the map details had been corrected, distances ascertained from measurements on the maps were generally more accurate than distances measured by surveys on the ground, especially in the measurement of cross-sections and particularly for points on cross-sections at and near their ends and far from the centerline.

A third project further proved, when tested by accurate control surveys, that survey project control established by the consultant was not sufficiently accurate on a local basis. On an over-all basis, however, specified accuracy had been achieved from error compensations. Maps were shifted 10 ft or more on cumulative bases. The designed centerline, when staked on the ground using planimetric detail as positioning origin, became placed approximately where intended. This approximate positioning could not have been achieved from the horizontally displaced maps had the position been established using accurate basic control, as initially surveyed by the U. S. Coast and Geodetic Survey, because of errors in the project control to which the stereoscopic models were oriented while mapping was being done.

Now that the centerline has been staked on the ground, a Tellurometer traverse originating on basic control established by the U. S. Coast and Geodetic Survey will be measured along the centerline. This traverse will serve as a check on the centerline staking and will consequently be a further check on accuracy of the maps and project control surveying.

Targets were designed in accordance with recommendations made in "Photographic Targets for Markers of Survey Control," by William T. Pryor, HRB Bull. 199, 1958, pp. 49-67.

a. Mr. Wright asked, if, in consequence of results reported, Illinois is still specifying project control should be surveyed to third order accuracy only?

b. Mr. Brantley answered third order accuracy measured in segments of 3 mi is adequate. Whenever closures are not made on basic control established at a 3-mi or smaller interval, third order accuracy for preliminary survey project control would not be adequate.

c. Mr. Pryor commented that closure errors occurring in measured project control surveys were often due to errors in azimuth rather than in distance measurement. Experience has shown consultants using the basic control established by the

U. S. Coast and Geodetic Survey as origin and closure for survey project control surveys must be sure the initial control point markers have not been moved since they were set. Movement of control points to prevent their destruction by construction crews, unless recognized and compensated for, causes many otherwise avoidable difficulties.

d. Mr. Brantley concluded by saying that a 1955 highway location project, which was mapped photogrammetrically, is now being accuracy tested by the Illinois Division of Highways. The tests on this survey project consist of accurately staking the designed centerline on the ground and checking all distance measurements by use of a Tellurometer. Sufficient measurements will be made on this project to ascertain whether or not errors in survey project control, made when the control was established by the consultant engaged to compile the maps, are in azimuth, in distance, or in both.

4. Robert J. Warren, Photogrammetric Engineer, Federal Projects Office, U. S. Bureau of Public Roads, read his paper regarding "Electrotape Use in Establishing Basic and Supplemental Control for Aerial Surveys."

Distance measurements by conventional chaining methods have been the biggest source of error encountered in aerial surveys. Such errors existed before aerial surverys were employed but had gone undetected or had been ignored.

Control surveys are now tied to monuments in the network of geodetic control established by the U. S. Coast and Geodetic Survey. In 1961, Region 9 began use of the Tellurometer for making ties to the geodetic network of basic control and for establishing basic control along highway routes to be surveyed by aerial methods. Control points set at an interval of 2 to 3 mi were position measured. Supplemental control between the basic control points and for horizontal position and elevation of pass points in stereoscopic models was accomplished by use of subtense bar and Wild T-2 theodolites, and self-leveling levels, as necessary.

Two Electrotapes, Model DM-20, were purchased in June 1962 at a cost of $13,102. They have been used in temperatures from -10 F to 90 F with the only problem encountered being discomfort of the instrument operators.

A comparison between Electrotape measurements and subtense bar measurements revealed the following: During an average 8-hr day, a 4-man field survey party, using a T-2 theodolite and two subtense bars, can measure 20 traverse distances, whereas the same crew using the Electrotape units would measure only 15 distances. The reliability of measurements obtained by the Electrotape, of course, is much better and justifies its use. Horizontal angles are measured concurrently with the subtense bar, whereas this is an additional operation when using electronic measuring equipment. Attempts to combine both have proven unsuccessful. An analysis of procedures in Region 9 showed considerable time is lost by the two operators of one Electrotape unit while the other two men are moving their unit to the next control point. To overcome these lost man-hours and to speed up the operation, a third Electrotape unit was purchased and placed in operation during June 1963. With three units A, B, and C, while units A and B are being used, Unit C will be set up on the next control point beyond Unit B. When the measurements between Units A and B are completed, Unit A will be moved to the next point beyond C—in the meantime Units B and C are being used. By this procedure, it is anticipated 24 to 26 measurements will be completed in an average 8-hr day. These three Electrotape units should also function very well in trilateration work for cadastral surveying in measuring the position of section corners and other points on property boundaries.

Distances measured with the subtense bar are 1,000 ft with a 12-ft subtense bar or shorter than 1,000 ft when shorter subtense bars are used. Brush was not a serious obstacle; usually lines of sight can be selected where a minimum of cutting will be required.

Power lines have not seriously affected work in Region 9, probably because few had been encountered close to the survey corridors. The most serious difficulty with the Electrotape seemed to be the fact that it required frequent calibration, especially after repair. Evidently repairs are made to correct operational deficiencies without ascertaining internal effects on distance measurement accuracy.

5. Fred B. Bales reviewed the paper, "Evaluation of Electronic Distance Measuring Device of Texas Highway Department," by Robert C. Rutland, Supervisory Design Engineer, Texas Highway Department. The paper is based on research conducted by the Highway Design Division of the Texas Highway Department in conjunction with the U. S. Bureau of Public Roads to determine the capabilities of the Electrotape for highway engineering surveys, especially those pertaining to accuracy, reliability, efficiency, economy, and maintenance.

a. M. D. Shelby said that only the Electrotape was being tested in Texas. Comparisons might be possible, however, between the Electrotape and the Tellurometer distance measurements on one survey project, where an early model of the Tellurometer was used. On this project the Tellurometer failed to make accurate measurements throughout areas where highway traffic was dense. But under similar circumstances no difficulty was encountered in making distance measurements with the Electrotape. Temperature and humidity measurements are required each time a distance measurement is made with the Electrotape.

b. Mr. Bales remarked the Virginia Department of Highways limits distance measurements to not less than 1,000 ft and preferably to longer distances in use of the Tellurometer.

c. Mr. Brantley commented the Illinois Division of Highways does not measure distances shorter than 1 mi with the Tellurometer.

6. Olin W. Mintzer reviewed the paper by Lloyd O. Herd, Ohio Department of Highways, on "The Problem of Unified Survey Control in Ohio."

In Ohio there are several networks of control surveys—horizontal and vertical. These networks were established by different surveying agencies and include networks by the U. S. Coast and Geodetic Survey, U. S. Geological Survey, U. S. Army Map Service, and local networks by the Cincinnati Metropolitan Topographic Survey, the Cleveland Regional Geodetic Survey, and surveys made for the cities of Columbus and Dayton, and the counties of Lucas and Mahoning. In addition, there are other local surveys. There is need for unification of all of the control established by such organizations and within the various local areas.

In 1945, the Ohio legislature adopted the Ohio State plane coordinate system by the enabling Senate Bill No. 299, the purpose of which was to describe, define, and officially adopt a system of plane coordinates for designating and stating the positions of points on the surface of the Earth within Ohio.

Mr. Herd referred to the method of adjusting State plane coordinates suggested by Mr. Pryor (See "Adjustment of State Plane Coordinates," HRB Bull. 199, 1958, pp. 2-13). Utilization of this adjustment procedure and a thorough analysis of the topography of Ohio revealed a combined adjustment factor of 1.000040 could be applied to the State plane coordinates of Ohio for both the north and south zones. By so doing, the difference between true distances measured on the ground and corresponding distances computed from plane coordinates of maps compiled on the adjusted datum would be 1:10,000 or smaller throughout the entire State. The difference between ground-measured distances and those computed from plane coordinates of maps compiled on the initial datum of the State plane coordinate system, as established for Ohio by the U. S. Coast and Geodetic Survey, will be much larger than 1:10,000 for a substantial part of each of the two plane coordiante zones. Adjustment of the State plane coordinates by 1.000040 merely establishes a new datum 836 ft above and parallel to the initial datum. Such adjustment does not alter the coordinate grid lines of the plane coordinate system nor does it affect bearing of lines ascertained by use of plane coordinates of basic control and highway survey points. In effect, after adjustment the distance between grid lines of the plane coordinate system and bearings remain the same. Only an expansion of map distance occurs between basic control points. Thus, the distances determined from plane coordinates of points on the maps compiled on the adjusted datum will agree, within practical limits, with distances measured on the ground.

The large number of control systems in Ohio make it desirable for the systems to be tied and adjusted to the basic control system established by the U. S. Coast and Geodetic Survey. This can be accomplished by making field survey ties between each of the separate systems of control surveys. Then the various systems can be adjusted and a unified system of control established for the entire State. Once this is done, all subsequent surveys tied to the unified system will become an integral part thereof and will serve to extend it on a progressive basis, making it more readily accessible for all survey purposes.

Inasmuch as aerial photogrammetry has proved to be an effective surveying procedure for highway location and design and for highway right-of-way acquisition, all control surveys made for photogrammetric purposes will add to and become an extension of the unified control suvery system of Ohio. Moreover, aero-triangulation methods, properly applied, yield sufficient accuracy for highway mapping requirements.

Professor Mintzer concluded presentation of Mr. Herd's paper by saying there is need for operational manuals for use by highway engineers and especially engineers who are making control surveys.

a. Robert G. Watts, Chief Engineer, Thomas Engineering Co., Columbus, Ohio, said his firm has cooperated with the Ohio Department of Highways using Geodimeter Models 4, 4A, and 4B in making control surveys for highway engineering purposes. The firm, however, has not had experience with the Geodimeter Model 4D.

b. Robert D. Miles asked why a revised manual is required inasmuch as a manual was prepared approximately 2 yr ago. Perhaps only new experiences need be included along with recommendations arising therefrom.

7. Arthur C. Quinnell gave a review of the paper "Idaho Highway Surveys with the Tellurometer," by Charles R. Shade, Chief Location Engineer, and Joseph R. Conner, Photogrammetrist, Idaho Department of Highways. The Idaho Department of Highways purchased a complete operating set of Tellurometer equipment, Model MRA/CW. This set of electronic distance measuring instruments has been used successfully during the past 3 yr in making control and cadastral surveys for highway location and design purposes. The Tellurometer measurements, after adjustment for effects of temperature and humidity, are converted to horizontal distances by electronic computers. Local microwave disturbances have caused errors of sufficient magnitude to require rejection of some Tellurometer measurements. Nevertheless, proper utilization of the system saves both time and money. The ruggedness of topography, sparse population, and long distances between existing markers of horizontal and vertical control make use of the Tellurometer especially effective in accuracy and economy for long surveys. In addition to extending basic control from the U. S. Coast and Geodetic Survey network to highway survey projects and the establishment of basic control along each highway route, another, perhaps the greatest, advantage of the Tellurometer is in establishing the horizontal position and elevation of supplemental points required for scaling and leveling stereoscopic models in precision topographic mapping by photogrammetric methods of highway routes for design.

To establish elevation for leveling stereoscopic models the Tellurometer is used to measure the slope distance and a T-2 theodolite to measure the vertical angle from each station marker for which both horizontal position and elevation are known. In rugged mountainous areas an average of from 4 to 5 hr of survey time has been saved in surveying with the Tellurometer for each elevation and horizontal control point measured.

The humidity over large portions of Idaho remains exceptionally stable at 15 to 25 percent. During the surveying season, range in temperature is large, however, extending from 120 F at 2:00 PM to as low as 60 F at 2:00 AM. In fact, a range of 20 to 30 F may occur between shaded and unshaded areas. As little as one variation in making reciprocal observations between survey stations resulted in measured elevations differing from 3 to 5 ft, making them unreliable for map control purposes. It is best to make reciprocal vertical angle and Tellurometer slope distance measurements simultaneously rather than allow an interval of time between reciprocal measurements.

a. Clair L. Arneson, U. S. Forest Service, questioned the validity of not making reciprocal measurements at the same time. Whereas simultaneously made measurements may check each other, such checking is no guarantee both are not mutually in error.

b. David S. Johnson remarked survey accuracies should be reported which are closed on basic control established by the U. S. Coast and Geodetic Survey.

8. Mr. Pryor made a brief report regarding a paper proposed by John F. Nickell, Photogrammetric Engineer, Missouri State Highway Commission, pertaining to Geodimeter surveying of traverses to establish horizontal control for the photogrammetric compilation of maps for highway location and design. The report will include methods of establishing on the ground the computed centerline of the designed highway and positioning horizontal control points for interchange construction and the use of trilateration techniques in surveying for bridges.

9. Mr. Pryor also gave an abstract of the paper by Gottfried Konecny, Department of Civil Engineering, University of New Brunswick, Canada. Since 1959 electronic surveying instruments have been used in the province of New Brunswick to measure the horizontal position of geodetic markers in control surveying. Experience with the Tellurometer Models MRA-1 and MRA-2 and the Model 4 Geodimeter is reported. Recently included are costs and accuracies of control surveys made with the Tellurometer Model MRA-3. The report contains an analysis of a dense network of 2,000 control stations positioned on the ground according to modern concepts. Due to the potentiality of electronic surveying instruments, this concept of positioning station markers is different from previous practice. Special experience in the establishment of control in the Canadian Rockies and in county surveys is disscussed. Explanation is made of an integrated use of plane coordinates in establishing a network of control, particularly for highway location and design, which is economical and effective.

10. Mr. Wright gave a resume of the paper by Benjamin H. Witter, Supervisory Electronic Technician, U. S. Army Map Service, on "Electronic Distance Measuring Devices." The Wild-Heerbrugg Co. of Switzerland has developed a system called Distomat which is expensive and, as yet, has not been demonstrated in the United States. The Fairchild Camera and Instrument Corp. has a contract with the United States Army to develop an electronic measuring system similar to the Tellurometer and Electrotape. At this time, the model has not been delivered. The Russians have made a good copy of the Geodimeter.

The Electrotape and Tellurometer employ a microwave radio beam. Both may, under certain conditions, be adversely affected by high-tension electric power lines, radar units, transmitters, and other sources of electrical disturbances. Haze, smoke, fog, dust, light rain, or light snow do not impede the operation of these instruments but may adversely affect the Geodimeter. The Geodimeter uses a beam of light as the measurement medium, and is used at night. Its operation is not affected by sources of electrical disturbances. Adequate accuracies are obtained with each of the three different electronic measuring systems when appropriately utilized.

The Electrotape is manufactured by the Cubic Corp., San Diego, Calif. The cost of the system is $12,000, including most of the accessories. The Geodimeter is manufactured by the AGA Corp. in Stockholm, Sweden. The price of the basic Model 4 instrument is slightly more than $6,800 and accessories cost $2,000. The Tellurometer is manufactured and distributed by Tellurometer Inc., of South Africa; the local address is 5451 Randolph Rd., Silver Spring, Md. The cost of the basic operation system is $9,800, plus $700 for accessories.

11. Mr. Arneson presented his paper on "Results of the U. S. Forest Service Stereotriangulation Bridging on the Virginia Highway Photogrammetric Test Project." The project is a segment of Interstate 66 in Fairfax County, Va., where the topography is rolling, land use ranges from rural to suburban, and vegetation is rather dense in some sections.

Forty-three photography flights were made over the test area using two separate aerial cameras. Aerial photographs were taken before and after the photographic targets were set on markers of basic control. Photographs were taken (with filters and without filters, when skies were clear, and when skies were overcast) at scales of 1,400, 1,050 700, and 350 ft to 1 in.

The identification and use of natural images on photography not containing targets presented a correlation problem between office and field. Field survey practices in measuring supplemental control—horizontal and vertical—to objects comprising natural images were not always successful in correctly marking each specific image so it could be appropriately identified by the photogrammetric instrument operators.

After instrument bridging had been accomplished, the photogrammetric measurements were used in electronic computers to determine the X, Y, and Z coordinates of control points and pass points. Wherever points lacked sufficient mathematical correlation they were rejected and the affected bridge was recomputed. Points rejected were invariably those which were questioned in identification from field to office.

Results of this test project indicate supplemental vertical control established by bridging is more accurate than supplemental horizontal control similarly established. Targets are needed on control points to achieve adequate accuracy in bridging of horizontal control. The white terminal segments of the legs of each photographic target are satisfactory for identifying the target on aerial photographs. Black materials are needed at the center of each target placed on a station marker.

Camera motion during the instant of exposure and poor resolution both result in fuzzy images. Generally, camera motion is more easy to detect than poor resolution. A resolution of 50 lines/mm is required if good bridging is to be achieved.

A least squares fitting of bridging measurements to the surveyed control was more easily obtained with small-scale than with large-scale photography. This merely means, however, an abundance of points are not as easily fitted together as a few. The average of an abundance of points, however, is more representative of bridging results. Camera movement during instant of exposure and errors in field control surveying affect results more with large-scale than with small-scale photography. A dark center and dull white ends on the legs of targets are required for best results.

Vertical photography at scales of 1,400 and 350 ft to 1 in. contain suitable scale relationships for bridging and mapping. Before mapping is undertaken, however, a second bridging should be measured with the photography of 350 ft to 1-in. scale, using supplemental control bridged using the photography of 1,400 ft to 1-in. scale. Correlation is first made by selection of images identifiable on both scales of photography. Inasmuch as the 350 ft to 1-in. scale photography is four times as large as the 1,400 ft to 1-in. scale photography, natural images on it are finitely smaller than on the larger scale photography; thus pinpointing control without the aid of targets is difficult. Targets placed on the ground before photographs were taken were spaced approximately 1,000 ft apart along the highway route. Using such targeted points, adequate photographic images of natural objects were selected to serve as pass points in bridging control by use of the large, 350 ft to 1-in. scale photography.

Fifty bridges have been measured and total cost for the photogrammetric bridging thus far accomplished is $8,600.

a. Mr. Sullivan mentioned costs were not segregated because no attempt was made to ascertain operational data. The purpose of the tests is to determine the feasibility of bridging supplemental control to scale and leveling each stereoscopic model formed from large-scale photography for precision mapping.

b. Mr. Arneson said the elemental objective of the test project is to establish guidelines, based on results from the test, for planning bridging work according to accuracy desired.

12. Professor Miles reviewed the paper proposed by Sandor A. Veres, Assistant Professor of Surveying and Mapping, Purdue University, on "Accuracy Requirements and Uses of Electronic Measuring Devices for Photogrammetric Contol Surveys." Essentially, the paper is a mathematical approach to the analysis of error and expectation from photogrammetric measurements. Discussed are the aspects of aerotriangulation for preliminary surveys and for cadastral surveys for procurement of highway rights-of-way. The next phase of the paper is discussion of error propagation in photogrammetry and electronic surveying. Experiments clearly indicate error propagation is homogeneous in photogrammetry, whether or not the measurements are made for establishment of horizontal or vertical control.

Mathematical equations developed indicate ground-surveyed control cannot be assumed to be without error, as is customary in surveying practice. Ground-surveyed control should have a much higher degree of accuracy than required in conventional surveying. Higher accuracy can be achieved by electronic surveying. Analysis of error propagation in electronic surveying indicates introduced errors are homogeneous, such as they are in photogrammetry. Consequently, electronic surveying and photogrammetry are ideal companions. Accuracy can be increased by mathematical computations.

Mr. Pryor commented adjustments made mathematically for errors of known magnitude can improve relative accuracy. Of course, mathematical adjustments are merely a distribution of error which will affect the least accurate measurements in an affirmative manner and the most accurate in a negative manner.

13. Mr. Sullivan gave a resume of the paper "Aerial Photography in the Kansas Courts," by O. E. Caruthers, Attorney State Highway Commission of Kansas. This paper pertains to use of aerial photography in preparation for and in presentation of evidence in condemnation cases to the courts of Kansas. Aerial photography, effectively used, reveals the facts. The paper is informative, although not technical. As an example, a land owner presented testimony supporting his claim of $14,000 in an appeal from a court award of $1,500. On consideration of the evidence, which included aerial photography by the State, the jury awarded an additional $4,800. In another case, the sight of an aerial photograph on an attorney's table prompted the landowner to change his testimony from level farm land to describing terraces accurately. Some court case citations are made to indicate the effect on witnesses and juries when aerial photographs are used.

14. John H. Wickham, Jr., Photogrammetry Systems Division, Keuffel and Esser Co., 7900 Old Georgetown Rd., Bethesda, Md., mentioned the firm's new analog system of measuring and recording X, Y, and Z dimensions in conjunction with double-projection photogrammetric instruments. The instrument can also be used on topographic maps to measure cross-sections and automatically record the cross-section dimensions. This instrument is known as the Electronic Coordinatograph and Recording System, ECARS.

15. Mr. Brantley gave a brief review of the paper by Mr. Herd, "Rights-of-Way Surveys by Photogrammetric Methods." First, an inventory was made regarding the horizontal and vertical control established throughout Ohio by the various control surveying organizations. Essentially, the paper pertains to bridging by use of precision photogrammetric instruments of horizontal and vertical control for cadastral survey purposes and for control of precision mapping by photogrammetric methods for highway location and design. The results obtained by use of optical train and double-projection instruments are presented in tabular form. Recommendations are made that measurements and mapping be accomplished at even fraction scales, such as 1:2,000 instead of 1:2,400, 1:1,000 instead of 1:1,200, and 1:500 instead of 1:480. In addition, the report contains recommendations for revision of certain sections of the Reference Guide Outline.

a. Mr. Pryor mentioned both double-projection and optical-train photogrammetric instruments can be utilized for bridging. The instrument used depends somewhat on availability, but more specifically on the length of bridges required. Longer bridges for establishing supplemental control may generally be made with optical-train instruments than with double-projection instruments. Each type of precision photogrammetric instrument has particular advantages.

The initiative in conducting research financed by Federal-aid HPR funds lies with the States. This is true whether the research pertains to materials, economics, traffic, or aerial surveys. To initiate a research project financed by HPR funds, a highway department should submit a research problem statement and an estimate of costs to the Division Engineer of Public Roads. Eventually, the proposal will be acted on in the Washington office of the U. S. Bureau of Public Roads, where all proposed research and development are correlated.

b. Mr. Wickham said before an instrument is selected, all aspects of the cost, operation, capabilities, and effectiveness should be known and taken into consideration.

16. Harold T. Rib reviewed the paper by George P. Katibah on "The Application of Precision Photogrammetric Methods to Rights-of-Way Relinquishment Surveys," a report of a research project approved by the U. S. Bureau of Public Roads for use of Federal-aid HPR funds. Essentially, targets were placed directly on control points, the positions of which had been surveyed previously. The aerial photographs were taken using a Zeiss RMK 15/23 aerial camera. Flight height for the photography was 1,500 ft, from which the 6-in. focal length camera produced photographs at a scale of 250 ft to 1-in. Enlargements of the aerial photographs, every other photograph in a series, were sent to the field for identification of targeted control points and points on construction survey lines. These enlargements also were used to delineate the boundary of properties to be relinquished from the original highway right-of-way purchase.

The Zeiss Stereoplanigraph Model C8 was used to measure X, Y, and Z coordinates to the nearest 0.01 mm at a stereoscopic model scale of 125 ft to 1 in. Such accuracy in measurement is equivalent to 0.05 ft on the ground. At the same time, the point measurements for the planimetric plot of each relinquishment right-of-way was completed at a scale of 50 ft to 1 in., the same scale used in preparation of construction plans for highways. After orientation of the stereoscopic models to basic control on which photographic targets had been placed, measurements were made from construction survey points to points on the boundary of each property to be relinquished.

Success in making photogrammetric measurements for cadastral purposes was directly related to having accurate control available for orientation of the stereoscopic models. This control had been surveyed by use of the Geodimeter. Adequate accuracy can be obtained by use of one horizontal control point each two or three stereoscopic models apart along the highway. The properties were not mapped to test the accuracy of the photogrammetric system utilized. Greater accuracy than actually obtained may be possible wherever demanded. In addition, savings were made by use of photogrammetric techniques as compared to what costs would have been had the relinquishment surveys been made by conventional methods on the ground. Generally, the average distance differences on three projects between measurements on the ground and those made photogrammetrically between points targeted on the ground is only 0.25 ft.

a. Professor Miles asked, "What is a relinquishment?"

b. Mr. Pryor answered that by California law it is possible to procure an entire parcel of land in lieu of obtaining a portion and to compensate the property owner for land acquired and for severance. Once the highway has been constructed, land in excess of that required for the highway right-of-way may then be sold; hence, use of the word relinquishment for such lands.

c. Mr. Johnson further explained relinquishment is necessary for obtaining Federal aid in the procurement of essential right-of-way. Federal-aid funds cannot be utilized for lands beyond portions needed for the highway right-of-way.

d. Mr. Rib said comparisons of the Stereoplanigraph Model C8 and survey methods on the ground are made on a plane coordinate basis. Differences, of course, do not necessarily mean photogrammetric measurements are being compared with absolute measurements to obtain an expression of accuracy.

17. Charles Pinnell reviewed the paper "Comparison of Two Techniques of Aerial Photography for Applications in Freeway Traffic Operations Studies," by William R. McCasland, Associate Research Engineer, Texas Transportation Institute, Texas A&M University. This paper pertains to the use of aerial photography in conjunction with traffic surveys (See also Sect. 81, Minutes of 12th Meeting; and Sect. 3, Minutes of 13th Meeting). Nine photography missions were made over the freeway section during peak hours of traffic movement. Experience pointed to the need for radio communication between the aircraft pilot and the ground surveillance crew, although such communication was not employed in this project.

The principal objectives of this research were to determine the (traffic) operational characteristics of the freeway and to ascertain the factors affecting the level of service offered to the motorist and to evaluate the two techniques of aerial photography and their applications to making traffic surveys and studying traffic movement under various operational conditions and characteristics.

Two aircraft were used each with a 24-in. focal length camera, one for taking single exposure photographs at appropriate intervals and the other for taking continuous-strip photography. The continuous-strip photographs were taken from a flight height of 1,000 ft and the single exposure photographs were taken successively along the freeway from a flight height of 2,500 ft. Only one photographic flight was made each day in the direction opposite to outbound traffic at the peak hour. All other photographic flights were made in the direction of the peak hour traffic.

Targets had been placed on the ground to serve as reference points for ascertaining the location of each motor vehicle by lane, direction of travel, and type of vehicle. Electronic computer programs were developed to use basic data obtained from the photography and compute all desired traffic characteristics. Experience from this survey indicated control point markers on the ground should have been placed closer together. Close placement of such markers would make the obtainment of data from the photographs easier.

a. Mr. Pryor commented on the continuous-strip photography and single-exposure (time-lapse) photography. Continuous-strip photography does not capture the position of one vehicle with respect to another at an instant. Positioning a vehicle on continuous-strip photographs is a function of the speed and direction of motion of the vehicle on the ground and of the aircraft in the air. Single exposure photographs capture a large number of vehicles on each exposure at an instant, revealing their spacing and their position in relation to each other and to the ground markers. A subsequent single photographic exposure, constituting a stereoscopic mate to the previous photograph, will reveal the position of the same vehicles and their spacing at another instant.

b. Mr. Pinnell said stereoscopes and parallax bars were used for examination of the aerial photographs. Aerial camera instability did not cause serious difficulty in continuous-strip photography. Targets were placed on the shoulders of the highway and used to define the location of vehicles. Targets at an interval (lengthwise along the highway) of 200 ft would have been much better than the targets placed at various spacings averaging about 1,000 ft apart. Moreover, an exact, constant, and identifiable interval would be best.

18. Mr. Quinnell suggested the Committee discuss other applications of aerial surveys.

a. Mr. Sullivan said aerial photography certainly can be applied to traffic surveying and analyses, especially in ascertaining the traffic capacity of highways and the effectiveness of traffic control systems, and in analyzing congestion problems.

b. Mr. Bales said specific development of measuring and recording devices for use with precision photogrammetric instruments is another special field in which additional data are obtainable. It would be well to make a comparison of the different types of such devices, especially with respect to their accuracy and efficiency.

c. Professor Mintzer mentioned research problem statement No. 21 regarding electronic computations and cadastral surveying. There is need for more information regarding possibilities of utilizing photogrammetry for cadastral surveying.

d. Mr. Anschutz said the State Highway Commission of Kansas has been cooperating with the U. S. Geological Survey in mapping drainage areas. This cooperation has extended beyond mapping per se and has included research into the aspects and causes of change in drainage ways and the effects of changes in land use on the run-off from drainage areas.

e. Mr. Pryor commended Erwin Sternberg, who, when he was a member of the P&AS Committee, prepared and presented a paper on "Drainage Studies from Aerial Surveys" (HRB Bull. 312, 1961, pp. 10-17). He also mentioned some of the possibilities of thermal sensing and conversion of infrared measurements to photographic imagery for visual examination. The number of applications of infrared imagery seems limited only by the initiative and imagination of the users. Inasmuch as infrared imagery can be obtained at any time of day or night, it can be used under conditions not permitting the taking of aerial photography. For example, infrared imagery can be obtained for traffic survey purposes during peak hours which occur before sunup and after sundown during the winter season. It may also be used to ascertain sources of granular material in river terraces, to classify road surfaces, to ascertain places of water emission from underground seepage, or to predict where icing will be most likely to occur.

19. Mr. Bales reported current successes of the Virginia Department of Highways in taking and use of color photography. In cooperation with the U. S. Coast and Geodetic Survey, aerial color photographs have been taken using super Anscochrome color reversal film. The color photographs were taken with a Wild aerial camera without filters. Exposure and development of the color film transparencies were by the U. S. Coast and Geodetic Survey. Photographic prints were made from the color transparencies by a commercial firm in Chicago. The cost of each print was $3.00. Results obtained were better than expectations for photographic interpretation.

20. Mr. Wright said Lockwood, Kessler, and Bartlett had been using an electronic computer program for computation of descriptions of land subdivisions and preparation of deed descriptions. These computations have been done on- and off-line, as desired.

A Calcomp high-speed digital plotter is used for plotting cross-sections and computed points of land subdivisions and deed descriptions using digital data therefor from the electronic computer. These automatic methods are time saving and effective.

21. E. M. Every reported Wisconsin is using a new Wild aerial camera. Recently, eight counties in southeast Wisconsin were photographed. For example, 600 sq mi of Brown County were included in about six photographs. The photographs were taken under contract by Chicago Aerial Surveys from a flight height of 22,000 ft with the 88-mm focal length camera. Photographs obtained at a scale of 6,300 ft to 1 in. contained excellent detail and were very effective for reconnaissance surveys and photographic interpretation of feasible highway routes.

Wisconsin has had continuous-strip photography taken at large scales. Such photography contains large variations in scale due to camera movement during flight. This movement is caused by camera response to tilts occurring in the aircraft. Paradoxically, better results have been obtained without the gyromount, the use of which is intended to reduce the effects of aircraft tilt.

Getting good contrast between photographic images in aerial photography has been difficult in the past. Now that the State-owned camera and the rented Wild RC-9, 88-mm focal length, cameras are in use, much better results have been obtained, especially in quality of images, including their contrast distinctions.

22. Mr. Anschutz said all communities containing 6 000 or more people, as well as some with populations of only 2,000, had been photographed in Kansas. A Wild RC-9 aerial camera was used, and as many as 144 sq mi are included in the ground area coverage of one photograph. The field of coverage is 120°. Once the negatives are on hand, uses for prints from the negatives, both contact and enlargements, increase as more operational units within the State Highway Commission of Kansas become acquainted with the benefits obtainable from use of such photography.

23. Mr. Johnson said in Connecticut photography is taken of highway routes in such a manner that the maps can be compiled in continuous strips for design. Oblique photographs are taken of various alternative route locations and interchange sites. Proposed route locations and interchange designs are delineated on such photographs using perspective techniques. In addition, aerial color photographs are taken to give the perspective delineators an insight into the colors within the area in which they are required to make the delineations. Thus, both physical and color balance are easy to achieve. Such delineations augment photographic mosaics and topographic maps in presentation of route locations and in the display of detailed designs in conferences and at public hearings.

24. Mr. Warren said use in Region 9 of the U. S. Bureau of Public Roads of color film negatives reduces the hazards of using color film positives in the field, because the negatives can be retained in the office and only the prints need be taken into the field.

The recent project in a rugged region of Colorado was photographed to determine the reliability of color film negatives for making measurements and photogrammetrically compiling topographic maps using contact prints made on 0.25-in. thick glass plates from such negatives. Map accuracy testing points were surveyed on the ground concurrently with establishment of supplemental control. Only the supplemental control (elevation and horizontal position of targets and identified natural image points) was furnished the consultant for compilation of the maps. The testing points, of course, were designated as those for which photogrammetric measurements were required, both horizontal position and elevation.

The same project was also photographed using black and white negative film and mapped a second time using glass plate transparencies printed therefrom. Topographic maps compiled by use of the Agfa color film photography and black and white film photography agreed very well. All test point measurements indicated accuracy requirements could easily be met by use of the aerial color film negative photography, which was much more useful for photographic interpretation than the black and white photography.

Photographic prints were made from the color film negatives using a Log-Etronic automatic dodging printer at a cost of $4.00 per print. A new Zeiss aerial camera was used (without filter) in taking the color film negative photography.

The benefits accruing from color film negative photography are many, as compared to use of other photography emulsions—color film positive or black and white. In addition, the color film negative photography can be stored in an air-conditioned vault except during use to print essential photographs on paper or on glass. There is no need to cut the rolls of film for use in photogrammetric instruments or for examination to accomplish photographic interpretation.

25. Mr. Quinnell stated that Montana will use the new Agfa color film for taking color film negatives. Due to the coating on the lens of the camera used a three-layer "sandwich" filter will be required with the color film.

26. Robert G. Watts said his firm (Thomas Engineering and Surveying Co., Columbus, Ohio) specializes in control surveying—not in photogrammetry. This firm has developed and uses special towers, one for the surveying instrument and one for the instrument man. The towers are made of steel, can be erected by two men, and each package can be carried. Both towers together weigh 320 to 330 lb. When erected, the towers are about 22 ft high and provide an instrument height of over 25 ft.

This surveying firm uses the Model 4 Geodimeter to make distance measurements and an IBM 1401 electronic computer to reduce the Geodimeter measurements to horizontal ground distances. Notekeeping errors are detected by the computer program and are immediately identified for attention of the surveying personnel.

Electronic computer output includes all input data and computed results in 35 spaces on a tabular sheet. Included are the horizontal position and elevation of each surveyed point. Key punching is a principal source of error. At the end of each day all survey party notes are left in the office. Results of measurements are known by noon the next day—in addition to horizontal position and elevation, errors and their causes are identified in the tabulation of input and output data. Both the raw unadjusted and adjusted data are included in the computation tabulations.

Distances of less than 3 mi are measured in most cases. The ground-measured distances are reduced to sea level distances and then to distances on datum initially established by the U. S. Coast and Geodetic Survey for the plane coordinate system of the State in which the control surveys are being made. Thus, for short distances, differences between ground-measured and map-determined distances are kept small. Nevertheless, the differences caused by curvature of the Earth and ground elevation are not reduced to insignificance by adjusting the datum of map compilation to an elevation where map and ground distances will agree within acceptable limits.

27. Mr. Arneson said the U. S. Forest Service had been using the Bausch and Lomb stereoscope on a trial basis. Contact prints of the aerial photographs are used. Scale differences between separate prints may be as large as 4 to 1. This stereoscope

has been very effective in the selection and marking of natural images to serve as pass points between bridging and mapping photography differing in scale.

The IBM 1401 electronic computer is less costly in computing bridges using measurements made with the Stereoplanigraph, because of its speed, than the IBM 650 computer. Zoom stereoscopes, costing about $2,000 each, are effective aids in selection and designation of image pass points on the bridging photography which will serve as supplemental control points on the mapping photography.

28. Mr. Brantley mentioned Illinois has 500 highway miles under consideration along which traffic accident investigations will be made. Aerial photography taken at a scale of 800 ft to 1 in., enlarged to a scale of 300 ft to 1 in., and assembled to form a photographic mosaic, will be used. Initially this work will be restricted to the Interstate System and will constitute part of a 20-State investigation of accidents being coordinated by the U. S. Bureau of Public Roads.

a. Mr. Johnson commented construction of an Interstate highway over an intersecting highway is worse than underpassing the intersecting highway, especially because of the new standards for bridge deck widths on the Interstate System.

b. Professor Eichler said underpassing requires widening to satisfy the visual concept of narrowing. The psychology of an unsatisfactory physical situation for the motor vehicle driver is a factor which must not be overlooked.

c. Mr. Anschutz remarked aerial photographs show the effects of apparent narrowing of a highway to the vehicle operator where an Interstate highway underpasses another highway. Oil on the pavement to mark the trace of the crossover of vehicles into left lanes of a multiple-lane highway and into the opposing lane of a 2-lane highway to get away from the narrowing effect of underpassing another highway.

d. Mr. Brantley said as-built plans of highways are not as effective as aerial photographs for portraying conditions, shapes, positions, etc., where accidents have occurred or are likley to occur. The photographic mosaics are in single sheets of suitable size for ease in handling and for binding and filing.

29. Mr. Anschutz mentioned the State Highway Commission of Kansas rented from Gordon Enterprises, North Hollywood, Calif., on a per diem basis (including shipping time), a continuous-strip aerial camera to take photographs for pavement condition surveying and inventory purposes. He continued by saying SUR/FAX techniques developed by Aero Service Corp. may displace continuous-strip photography because the resolution of continuous-strip photography is not as good as desired. The SUR/FAX technique uses a 35- or 70-mm gun camera converted from the machine gun.

30. Professor Mintzer asked if someone knew the price of the analytic plotter, civilian type, developed by U. V. Helava and manufactured in Italy for the OMI Corp. of America.

a. Mr. Pryor answered that the price of the AP/C stereoscopic plotter ranges from $100,000 to $120,000.

b. Professor Mintzer also asked about the largest size contact screen available for offset copying and printing plan sheets.

(1) Mr. Anschutz said the size is 24 by 26 in.

(2) Mr. Brantley said Illinois has a screen of 30 by 40 in. with 120 lines/in.

(3) Mr. Every said Wisconsin uses a screen 30 in. square which also contains 120 lines/in.

31. Professor Mintzer reported on some research work in photographic interpretation at the Ohio State University for the Ohio Department of Highways. Photographic interpretation is correlated with geology and soils boring and testing. Various types of aerial film, camera filters, and photography scales were used. Also, variations in soil boring plans were employed. This was done to ascertain which combinations will assure best results in photographic interpretation for highway location and design. Infrared photography has not been effective in determination of peat bogs.

An aerial camera with focal length of $8\frac{1}{4}$ in. was used. In the future, Ohio will use a rented Zeiss aerial camera of 6-in. focal length.

a. Mr. Warren asked whether or not the inventory made of control established for Ohio included field checking to ascertain whether or not the station markers were in place as described and to evaluate the accuracy of control.

b. Professor Mintzer answered that the inventory comprised the compilation of a list of control from available sources only. The accuracy rating of each control point, of course, as mentioned in the source, will be included.

32. Mr. Quinnell reported the Montana State Highway Commission conducted an experiment to test the effectiveness of various colors for photographic targets with respect to image quality in stereoscopic models and to the accuracy with which the stereoscopic models could be oriented to scale and leveled for mapping work.

White crosses show reflection characteristics resulting in a floating condition with respect to surrounding ground. Image movement due to forward motion of the aircraft was calculated to be less than ½ ft on the ground and less than 0.001 in. on the photographs. Consequently, such movement was not considered to be the cause of some targets having the appearance on the stereoscopic model of floating. Twelve different color sequences were used. The colors were painted on plywood strips ⅜ in. thick, 6 in. wide, and 4 ft long to form four legs of a cross centered on the marker of the survey control point. The colors and targets were used in this sequence: medium gray, medium gray, dark gray, dark gray, light gray, medium gray, black, white, blaze orange, highway orange, medium orange, and light orange.

The plywood strips were painted once manually with flat paint using a brush—not a spray. Eleven of the targets were placed about 50 ft apart on pasture land containing some dead grass and weeds. The black cross, however, was placed on a dirt road where the ground tonal quality was light. A camera equipped with a Wild Aviogon lens was used at a height of 3,000 ft above the ground to take the photography. Camera shutter speed was $1/500$ sec. The aperture was f/5.6 and the aircraft flying speed 125 mph. Single weight matte prints and transparencies on glass 0.06 in. thick were made. The prints were examined stereoscopically by use of pocket-size lens stereoscopes. The photographic quality of the targets was also examined in stereoscopic models formed in the Kelsh double-projection instrument, utilizing a 5 diam projection ratio.

The medium and dark gray crosses were barely discernible, and the geometric configuration of the symmetrically constructed crosses were somewhat altered and blended with the tone of the surrounding ground and ground cover. The blaze and light orange crosses appeared large, bright, and conspicuous on the photographic prints. On close examination of the stereoscopic model, however, there was evidence of a definite fuzziness at the intersection of the legs of each cross, and possibly some reflection. The medium orange and highway orange crosses appeared to be narrow at the extreme outer end of the legs and somewhat blurry at the center intersection of the legs of each cross. These targets appeared to be skinny and frail. The light gray and white crosses appeared to be firm and retained their geometrical pattern more vividly than the other crosses. There was no apparent infringement of the light gray area of the cross over the mid-gray tone of the pasture cover and ground. No difficulty was encountered in placement of the measuring mark at the exact center of the cross projected by the Kelsh instrument. The black cross, which had been placed on a dirt road having characteristics of most earthen and gravel surface roads, retained its geometrical pattern and appeared to be more flush with the surface of the ground than the other targets. Consequently, on areas where the ground and vegetation will result in a light tone on aerial photographs, a black cross would be better and give more accurate results than a white cross, especially for measuring elevations in a stereoscopic model. Apparently, dodging in the printing processes will not alter this conclusion.

Generally, the photographic images of white targets are cotton fuzzy and have the appearance of being raised with respect to the surrounding ground, and, therefore, are not satisfactory. Also most yellow targets have a similar deficiency. The oranges were better than most of the others. Pale gray proved to be best. "Dirty" white may be used on the ends of the legs of targets for readily finding them.

The legs of the targets are held together by two bolts at the center. One bolt is removed and the strips folded each time a target is recovered and moved to a new location for placement on another survey marker.

Undoubtedly, criteria for placement of targets should be ascertained on a qualitative basis while on the ground by field survey personnel having had sufficient experience in use of the double-projection or other precision photogrammetric instruments. A black cross must be used on county roads, on alkali flats, and on granulated quartz and mica surface areas. A light gray cross is more satisfactory in areas where the ground and vegetative cover prevent an extremely light color tone on the photographs. All targets used in this experiment were one color throughout. There was not a variation in color between the ends and the center portions of each target.

a. Mr. Wickham asked whether or not the Keuffel and Esser firm would be justified in manufacturing photographic targets and making them available for use on highway survey projects and, if so, what type, (shape, size, and color) would be most useful.

b. Consensus of group at meeting was no one target would be suitable for all purposes, with the exception perhaps of shape, which would be cross-type for placement on markers of horizontal control points. The color tone of a photographic target, to be effective, must be selected according to the color tone the surrounding ground and adjacent vegetation will cause on the aerial photographs.

c. Mr. Warren said Region 9 had found lightweight plastic material is satisfactory, although it must be securely fastened to the ground. This can be done by placing grommets in the plastic to prevent tearing of targets. Also, canvas has been found to be satisfactory.

d. Mr. Quinnell said plastic has not served well in Montana because of damage by wind and animals.

e. Mr. Anschutz said the plastic used for targets in Kansas has withstood abuse and traffic. Animals are not harmed when they eat the plastic strips, because the plastic is made from soy bean vegetal materials. The greatest damage and loss of targets in Kansas is caused by grasshoppers. Three men in a crew can place 33 targets for each mile of highway in an hour. Targets are placed approximately 500 ft apart on each side and proper distance away from and along the center.

f. Mr. Quinnell said the Montana State Highway Commission is planning to test a new 6-in. focal length aerial camera. Photography will be used in a Stereoplanigraph Model C8, operated by the U. S. Forest Service.

33. Joe V. Evans, Georgia State Highway Department, said Georgia has been endeavoring to obtain better accuracy in vertical measurements made photogrammetrically. Instrumentation tests made thus far are not conclusive. The tests will be continued on a coordinate-grid basis within a test area where horizontal and vertical control are measured accurately at the intersection of each coordinate-grid point on the ground.

34. Professor Eichler mentioned research in analytical photogrammetry is under way at Georgia Institute of Technology. An ordinary (monocular) comparator, however, is not accurate enough. To be fully effective, a stereoscopic comparator is needed.

a. Mr. Pryor mentioned there are several stereoscopic comparators available. Two stereocomparators, which seem to be effective and independent from changes in room temperatures and humidity, are those manufactured by Hilger and Watts in England, and by the Zeiss firm in Germany. Generally, stereocomparators cost approximately one-half as much as optical-train stereophotogrammetric instruments. Consequently, the general price of a stereocomparator is approximately $40,000 to $50,000, including importation and other charges.

b. Professor Mintzer said papers published in "The Photogrammetric Record" contain much vital information regarding use of stereocomparators and successes obtained in bridging of control by their use. "The Photogrammetric Record" is a publication of The Photogrammetric Society, 24 Bruton St., London, W.1, England. The subscription price is $3.70/yr for the two issues published.

35. Mr. Shelby mentioned the Texas Highway Department has research projects under way to test the Auto-trol and the Electrotape. Data will be obtained to evaluate the Auto-trol as a cross-section measuring accessory for use with the double-projection photogrammetric instruments, and the Electrotape for establishing basic con-

trol, if sufficiently accurate, and supplemental control, if economically feasible.

a. L. W. Verner said the State Highway Department of Georgia had a survey project in the Atlanta area where all excavation and embankment quantities were being measured by ground survey methods and also by photogrammetric methods. Results will provide a comparison between the methods.

b. Mr. Bales said Virginia Department of Highways had had difficulty where field survey parties had not done good surveying work. Significant errors (differences between survey measurements made on the ground and measurements made photogrammetrically) were evident wherever cross-sections measured on the ground were not along a line of 90^0 to the highway centerline.

c. Mr. Watts remarked it is regrettable highway engineers and photogrammetric engineering firms use "stake punchers" to do vital work especially when well-qualified professional engineers and surveyors should be doing the essential control surveying. Maps can be no better than the control on which they are based.

d. Professor Mintzer asked for a quotation regarding the price of the Model M2 stereoscopic plotter, manufactured by the Belfort Instrument Co., 4 North Central Ave., Baltimore, Md.

e. Mr. Wickham answered $12,000 for the two-projector unit and $14,400 for the three-projector unit.

f. Mr. Warren made a comment regarding measurement of quantities by photogrammetric methods, and then asked what proof there would be a designed construction project had been staked on the ground according to the plans if the slope staking book should be lost.

g. Both Mr. Shelby and Mr. Anschutz answered that an electronic computer tabulation of data from the design computations will serve this purpose. In Texas the grade and slope stakes are set by the construction contractor.

36. Mr. Sullivan made a brief report regarding some practices of the U. S. Forest Service. The Comptroller General of the United States has ruled users of roads built by the U. S. Forest Service must share in the cost of their construction as well as in their maintenance. The problems are computing proportionate shares of cost by ascertaining the traffic capacity, the number of users, and actual weight of loads, such as trucks hauling timber and also hauling ore from mines. Generally, it is desirable to make capital recovery in 20 yr on a 6 percent interest basis. U. S. Forest Service Roads are financed from general funds, not from highway trust funds. Such a responsibility comprises a significant inventory problem, both for single- and 2-lane roads. The U. S. Forest Service is now endeavoring to select a representative section of roads to ascertain capacity, construction and maintenance costs, etc.

37. Professor Miles referred to a paper "Aerial Photography Applied to Traffic Studies," by W. F. Howes, graduate assistant, and R. D. Miles, Research Engineer, Purdue University. The report pertains to the techniques employed in obtaining data regarding traffic by use of aerial photography. Over 25,000 units of data were ascertained and analyzed statistically to get answers regarding vehicle speed, number of vehicles, and traffic density. In addition, aerial photography was used to analyze vehicle acceleration, and merging, diverging, weaving, and passing patterns throughout an extended section of highway.

Time-lapse photographs were taken. On this particular project, a stereoscopic overlap of about 72 percent assured nearly all of the vehicles on the highway would appear in each successive pair of time-lapse photographs which were taken at an interval of approximately 3 sec between each separate exposure.

Among the auxiliary benefits of aerial photography in making traffic surveys is that the environment in which the traffic is moving is portrayed. Having the environment available enhances the value of the traffic data obtained, because the investigator is given reasons for unusual traffic movements.

a. Mr. Sullivan remarked sequentially exposed, finite format photography is an excellent supplemental medium for gathering traffic data. It is doubtful the photography will supplant entirely investigative techniques employed on the ground.

b. Professor Miles continued by saying another purpose for which aerial photography can be used in conjunction with traffic surveys is to ascertain the economic impact of highways on bordering land use and to determine the effect on unit value of bordering and nearby land.

38. Mr. Pryor outlined the principles inherent in modifying State plane coordinates of basic control points on datum of the initially established system of State plane coordinates for use on an adjusted datum to reduce the difference between distances measured on the ground and those determined from plane coordinates of maps compiled on the adjusted datum to negligible quantities. Basically, the datum adjustment comprises a raising or lowering of the plane of projection. The magnitude of adjustment required for the plane, which constitutes a mapping datum, is ascertained by analyzing the elevation of the ground throughout each zone and determining the difference between the elevation of the ground and that of the initial datum at each significant geographic location within the zone. Then the position for an adjusted datum is established where the datum will not be more than 2,090 ft below or above any ground point within the area throughout which the adjusted datum is to apply. Consequently, the particular geographic position of the area in relation to the central latitude of Lambert Conformal Systems of projection and to the central meridian of the Transverse Mercator Systems of projection must be considered, as well as the actual elevation of the ground. An adjustment may be made throughout an entire zone in a State such as Ohio or throughout a geographic portion of a zone in a State such as Kansas where low elevations exist in the east and high elevations in the west.

Once a datum adjustment has been achieved so the difference between ground-measured distances and distances ascertained from plane coordinates of points on the maps are not greater than 1:10,000, the differences may be ignored in subsequent surveying and mapping and in use of all maps compiled on the adjusted datum. If the datum is not adjusted before the mapping is accomplished and the maps are compiled on the initial datum, the difference between each ground-measured distance and its length as determined from the plane coordinates of its ending points on the maps is usually so large, adjustment for the difference of each distance must be made when the designed highways are staked on the ground and when rights-of-way boundaries are staked. Unless this is done, discrepancies exist between distances on the ground and those on the maps that are so large as to cause significant displacements from intended position. In addition, the tangent distance between the end of one curve and the beginning of another and distance along each curve, as designed and as defined by plane coordinates of the maps, are not in agreement with distances which must be measured on the ground to place the highway where designed. Consequently, the staked and constructed highway and right-of-way dimensions will not be in agreement with dimensions of the construction plans.

a. Mr. Anschutz said the State Highway Commission of Kansas is using plane coordinates of points on an adjusted datum in defining the boundaries of right-of-way for condemnation cases in courts. Also, the State Highway Commission of Kansas is similarly defining the property corners initially marked as section corners by rocks on which the standard markings were initially engraved. Reason for defining these points by plane coordinates is to resolve for all time the uncertainties which occur when a rock has been moved from its initially set position. Corner marker movement may be accidental or deliberate, but in any case, such movement results in confusion regarding position of the property boundary. The exact position of each property corner or boundary can be reestablished once its plane coordinates on an adjusted datum, where initially set on the ground, have been established.

b. Professor Mintzer emphasized that, when the initially established datum of the plane coordinate system is not adjusted to conform with the ground elevation throughout the area of application, positioning of designed highway centerlines can be accomplished by relating the intended position to planimetric features. For example, if the distance is measured between two points on a tangent to two separate planimetric features, the same distances can be measured on the ground to set the points. Then the tangent can be staked on the ground between the points. If this procedure is followed for each successive tangent, the tangents can be intersected, the central angle measured. and the curves staked between the tangents as indicated on the plans. Consequently, the staked centerline will represent ground distances.

c. Mr. Pryor said the practice described by Professor Mintzer will cause the staked highway dimensions to differ from dimensions on the plans. Also, positioning on the ground will be in error the amount each planimeteric feature used as reference for transferring designed alignment from the plans to the ground is displaced on the maps. If, however, the plans are based on maps compiled on an adjusted datum, coordinates of curve points can be used to compute the staking tie distance and bearing between these points and the nearest basic control point for which a station marker was set before the mapping was undertaken. Thus, the highway centerline can be staked on the ground where designed using dimensions of the exactly computed highway centerline on the plans. No alterations need occur in the staking processes because of differences between map and ground distances.

39. Mr. Pryor made a brief explanation regarding use of the remote baseline method of measuring horizontal and vertical control. (See "Remote Base Line Method of Measuring Horizontal and Vertical Control," by W. T. Pryor, in HRB Bull. 354, 1962, pp. 32-50.) Essentially, the remote baseline method requires use of a precision angle measuring instrument and a 100- or 200-ft steel tape, depending on the length of lines to be measured. The remote baseline method is a modification (not a direct adaptation) of the subtense bar method of measuring horizontal distances. The remote baseline need not be perpendicular to the line of sight of the angle measuring instrument. One angle is measured between one end of the baseline and a point on the baseline somewhere about halfway between its ends. The other angle is measured between this point and the other end of the baseline. From the length of the two separate, but contiguous segments of the baseline and the two measured angles, developed equations make it possible to compute the horizontal distance between the instrument and each one of the three points on the base line—the ends and the median point—as desired.

Inasmuch as two angles are measured and two separate baseline segments are used, the equations provide two answers for each of the three horizontal distances. When these answers differ more than the permissible accuracy tolerances, the difference indicates need for remeasuring the angles and remote baseline segments.

a. Mr. Anschutz said the State Highway Commission of Kansas achieved effective results with remote baseline techniques for establishing supplemental control in the City of Topeka. The angle measuring instrument was placed on the top of tall buildings and the remote baseline measurements were made by the steel tape in the street areas visible from the instrument. By employing the remote baseline method in this manner, the surveying crew was not interfered with by traffic or by pedestrians.

b. Mr. Warren said amazing accuracy had been obtained in Region 9 using the remote baseline method of measurement.

c. Mr. Anschutz said the remote baseline method was used for expressway construction surveying in the Topeka area and for measurement of quantities during construction for progress payments to contractors. Such use, of course, applied to establishment of supplemental control from which aerial photographs were oriented in precision photogrammetric instruments to make the measurements for computation of quantities.

15TH MEETING, JANUARY 16, 1964
(Washington, D. C.)

1. Roy C. Edgerton of the Highway Research Board said there are several committees of the Board interested in utilization of aerial surveys for highway engineering purposes, for example, the committee on surface drainage and the committee concerned with the legal problems associated with surface drainage. The use of photogrammetry and other phases of aerial surveying for hydrology and for ascertaining the relationship of surface drainage and legal responsibilities need to be correlated.

Traffic engineers are beginning to make greater use of aerial surveys, and the P&AS Committee has been instrumental in having papers presented on the subject at previous meetings of the Highway Research Board. Further expansion in utilizations of aerial surveys would be commendable. Edgerton said the Highway Research Board looks to the P&AS Committee for guidance and recommendations.

2. Morris M. Abrams' U. S. Bureau of Public Roads paper on "Photogrammetry and Highway Law" contains citations from court cases, including rules for admission of evidence and circumstances under which aerial photography and photogrammetrically made measurements are admissible as evidence. The paper is broad in scope and reveals two signficant facts. Aerial photography and photogrammetrically made measurements serve a useful purpose in courts but are not used as much as they could be. Greater benefits in the courts are possible once the legal profession and engineers obtain a better understanding of how such benefits are attained.

a. M. D. Shelby asked whether or not the author had defined photogrammetry as surveying and had related photogrammetrically made measurements to measurements made on the ground.

b. Mr. Abrams answered only one case could be cited where such has been done. Unfortunately, statutes almost prohibit use of the word photogrammetry to mean surveying. Consequently, laws written before photogrammetry became feasible as a precise surveying technique must be revised.

c. Mr. Shelby said legal-minded people insist land surveys must be made on the ground. The Committee should do whatever it can to get statutes revised. Revisions should be made which will admit use of the words photogrammetry and photogrammetrically made measurements in the same manner as surveying and measurements made on the ground are admitted.

d. Bernard J. Colner, U. S. Bureau of Public Roads, said an investigation should be made to ascertain which States have accepted photogrammetrically made measurements in courts for cadastral purposes.

e. Mr. Abrams said there are no cases as yet found wherein photogrammetrically made measurements have been presented to and accepted by the courts for determining excavation and embankment quantities.

f. Clair L. Arneson, U. S. Forest Service, said cadastral surveying had been done by the Forest Service using precision photogrammetric methods to resurvey lands where property corners had been lost or the position of some corners was in question.

g. Mr. Abrams said no cases, thus far, can be found and cited where photogrammetrically made measurements have been challenged in cadastral surveying.

h. William T. Pryor commended Mr. Abrams for the excellence of his paper. The numerous cases reviewed and cited show there is a lack of understanding in legal circles of the feasible use of aerial photographs—both in photographic interpretation and in precision measurement by photogrammetric methods.

i. Mr. Abrams said there is generally a 10-yr lag between applications and obtainment of knowledge regarding new possibilities. Utilizations of aerial photography and photogrammetrically made measurements by the courts are no exception.

j. Mr. Edgerton said discussions thus far merely emphasize need for the legal committee, the P&AS Committee, and other like-minded groups to work together to attain a mutual understanding of problems and how they can best be solved through use of aerial photography and photogrammetry.

k. John V. Sharp, IBM Corporation, said photogrammetrically made measurements are merely an extension of measurements made on the ground, because all precision measurements made by use of aerial photography for surveying purposes must be correlated with and originated on points for which position has been established by surveys on the ground.

l. Mr. Abrams mentioned judges rule land surveys must be made on the ground. These rulings, of course, are predicated on current law, which was enacted before precision photogrammetry, in many cases, was a possibility. Where a difference has occurred between the area of a tract of land measured by surveys on the ground and that measured by photogrammetric methods, decisions by judges have been made against the admissibility of photogrammetrically made measurements despite the fact it was proven the photogrammetric measurements were correct and the other measurements were in error.

m. Mr. Shelby asked if engineers should not endeavor to get statutes changed. Engineers, 10 yr ahead of lawyers in knowledge of capabilities in aerial surveying, are better qualified than others to attempt to get the laws appropriately revised.

n. David S. Johnson said Connecticut had revised its statutes to permit the use of maps compiled by photogrammetric methods for filing State highway layouts. Statutes pertaining to cadastral surveys made on the ground should be assembled from each of the States. Then recommendations for legalization of photogrammetrically made measurements for cadastral purposes should be made.

o. Mr. Abrams said changing the statutes would speed the process of acceptance by the courts of photogrammetrically made measurements. Unless the statutes are changed, gaining acceptance will be slow and difficult.

p. George W. Habel, Jr., Virginia Department of Highways, said contractors in Virginia were beginning to use photogrammetric methods to check the measurements of engineers, because construction contractors have become aware of the general reliability and accuracy of photogrammetrically made measurements and their superiority to measurements made by the usual, less accurate methods on the ground.

3. Orville E. Caruthers, Jr., Kansas State Highway Commission, said the key to acceptance of aerial photographs and photogrammetrically made measurements by a court is what is being presented and why. Generally, challenges to admission in courts become acceptable only when it can be proved the photographs or the photogrammetrically made measurements are not relevant to the case.

a. Mr. Colner commented users of photogrammetrically made measurements should be certain of their accuracy before they are presented in courts.

b. Mr. Pryor said it would be unusual for a survey made on the ground to have been accuracy tested before presentation of its measurements in court. Perhaps it is not so much a matter of testing the accuracy of a photogrammetrically made measurement ahead of utilization in a court as it would be of establishing photogrammetrically made measurements, properly made by competent people, can be sufficiently accurate. A stereoscopic model cannot be utilized until all discrepancies in control within its limits have been eliminated and, therefore, there is much less likelihood of gross errors occurring as they do in ground surveying, such as recording a bearing in the wrong quadrant or the omission of a tape length or 10-ft increment thereof in distance notations.

4. William R. McCasland, Texas Transportation Institute, Texas A&M University, made a few remarks regarding research aerial photography for study of freeway traffic operations. Two of the significant objectives of the research undertaken were to ascertain which type of aerial photography—continuous-strip or time-lapse—would be best for traffic survey purposes and to learn how much can be obtained from photography which would be usable for accumulating and analyzing traffic data in making freeway traffic operation studies. Whereas each type of photography has its advantages and disadvantages, it was concluded time-lapse photographs were better than continuous-strip photographs.

a. Mr. Colner asked what are the problems of taking aerial photographs at specific times. Some users of aerial photography have had difficulty, caused usually by weather and time of day, in getting photographs taken when they would be most beneficial.

b. Mr. McCasland answered that much planning is required for taking and using aerial photography for traffic survey purposes to overcome difficulties usually encountered. Unfortunately, bad weather does interfere because it cannot be controlled or reliably anticipated. Use of aerial photography is both possible and practical for control of parking.

5. Frederick E. Behn, Ohio Department of Highways, mentioned Ohio is utilizing a modified Model 4 Geodimeter for electronic surveying during daylight hours. This new model of the Geodimeter has many advantages for highway surveying purposes, as compared to previous models. Distances which may be measured with the modified Model 4, when used during daylight hours, are not as long as they might be if the Geodimeter is used during nighttime hours, as are other models of the instrument.

Dan Radmanovich of California said daylight use of the Model 4 Geodimeter has been made possible by the addition of a different power pack.

6. Mr. Colner mentioned the U. S. Bureau of Public Roads had negotiated a contract with International Business Machines Corporation for research in image processin by electronic computation methods. Tentative output from the image processing will be automatically determined digital terrain models, recorded data pertaining thereto for any particular use desired, and printing of orthophotographs therefrom.

a. Mr. Sharp amplified Mr. Colner's remarks by saying aerial vertical photographs are being placed image by image in an electronic computer and map data and maps are coming out. The current significant problem is not operational but is the economical attainment of desired accuracy.

b. Mr. Arneson asked whether or not the stereoscopic models ascertained by the electronic computation techniques from the stereo-comparator-measured photographic coordinates are recorded in State plane coordinates or in relation to an established baseline.

c. Mr. Sharp answered that any desired system of coordinates can be used. After the individual point measurements are made successively on the aerial photographs, all aerial camera distortions and the displacements caused by film shrinkage, atmospheric refraction, and Earth curvature are removed from the measurements by mathematical computation procedures. Data from the photography are measured and corrected point by point, utilizing from 10 million to 100 million points in each stereoscopic model.

7. Olin W. Mintzer mentioned utilizing the system of State plane coordinates for all control surveys and encouraging all surveying groups to utilize the same system for both construction and cadastral purposes should result in improved accuracy and in an economical extension of the planned system of control. One of the problems will be correlating all control from the different agencies into the uniform State plane coordinate system. The network extension should place control points along highways where they will be readily accessible. All control established should be appropriately classified according to its specific accuracy. One of the previous handicaps to establishment of control was lack of survey parties with sufficient experience and appropriat equipment. One or more control survey parties could be kept busy throughout each year establishing extensions to the recommended network of control.

By law, property boundaries and right-of-way parcels must be described by metes and bounds. Consequently, adoption of the State plane coordinate system would relate all surveys to the same basic control and each survey would eventually become an integral part of the network.

a. Herbert L. Brantley asked who will pay for all the control surveying recommended. He continued by saying Illinois needs an agency to govern the preservation of all markers of survey control. Each year there is a substantial loss of control point markers through what appears to be negligent and inadvertent destruction.

b. James I. Taylor, the Ohio State University, replied that control surveying should be done on a progressive basis according to an agreed plan. In this way, the cost of establishing control would be defrayed by each surveying group engaged in making surveys for specific purposes.

c. Dr. Konecny mentioned cooperation in the province of New Brunswick in planning and establishing basic control is achieving for the Canadian province what is recommended by Mr. Taylor for Ohio.

d. Mr. Taylor contined by emphasizing all basic control and engineering surveys should originate on and close on basic control established by the U. S. Coast and Geodetic Survey. This is the only way in which a unified system of control can be established and extended and its accuracy ascertained through engineering surveys.

e. Professor Mintzer asked Dr. Konecny what group or agency does the basic control surveying in New Brunswick.

f. Dr. Konecny said a committee composed of approximately 20 people meets about once a month in New Brunswick. Members of this committee separately represent several government agencies. Consequently, the plans for control surveying, which the committee develops, are adequate to serve all needs. Financing of the control surveying is also cooperative among the interested agencies.

g. Robert G. Watts said all surveying done by his firm (Thomas Engineering and Surveying Co., Columbus, Ohio) in Ohio originates on and closes on markers of the basic control system established in the State. As the control surveying is accomplished between such ties, additional markers are set which serve as an extension of the network. Unfortunately, highway construction and other activities destroy many markers each year. The value of much of the basic control surveying is lost because station markers are not set along highway surveys during construction to preserve position and elevation points established during the construction operations.

h. Dr. Konecny said station markers in the basic network of control in New Brunswick also get destroyed from time to time. Since the control surveying committee was established in 1959, there has been a loss of approximately 5 percent of the station markers set. Loss is due to negligence, to inadvertence, and to other causes, some resulting from people not knowing or caring what the markers are.

8. Robert C. Rutland, Texas Highway Department, remarked Texas had modified the Auto-trol to make the instrument more effective for the electronic computer program Texas has been successfully using. Texas will undertake photogrammetric bridging to establish supplemental control using both the optical-train and double-projection instruments.

a. John O. Eichler commented surveying instruments obtained from Japanese manufacturers need repair often. Repair is also difficult because of the quality of the instruments and the parts available.

b. Mr. Shelby said the purchasing staff of the Texas Highway Department has been challenging engineers in the Department for rejecting surveying instruments made in Japan. The challenge is made on the basis of initial cost only. Unfortunately, the initial cost of surveying instruments is only part of the cost of their use. More significant are those which occur when instruments are not adequate for the purposes, do not stay in adjustment, and need repair often. Waiting for replacement of inoperable instruments is a waste of both time and money. A few additional dollars in purchasing accurate, serviceable, and reliable instruments save both time and money.

9. R. R. Beige, Jr., Kansas State Highway Commission, said that State is using aerial color film of the Ektochrome and Agfa types similar to use made of such photography in Region 9 of the U. S. Bureau of Public Roads. Experience shows aerial color film will penetate shadows very well. Details captured by color film in shaded areas are much superior to the details recorded by panchromatic emulsions. Kansas has experienced difficulty with the Auto-trol. For some unexplained reason, it stops recording distances at certain places. At present, the Auto-trol is being modified to eliminate some of the mechanical problems which seem to be contributing to this defect.

10. Charles E. McNoldy said in Pennsylvania, the character of topography and size of rivers require many bridges as long as, or longer than, 2,000 ft. Much of the precision surveying for obtaining data for bridge design and staking piers and abutments of designed bridges for construction has been done by triangulation.

Mr. McNoldy asked whether or not States have utilized the Geodimeter or other electronic distance measuring instruments for such purposes, and if so used, have the measurements been accepted by construction engineers.

a. John F. Nickell, Missouri State Highway Commission, said Missouri had used the Tellurometer to check precision surveying accomplished by usual methods on the ground for highway bridges and other purposes.

b. Dr. Konecny mentioned experience in New Brunswick indicated Geodimeter measurements are more accurate than measurements achieved by triangulation or by the usual traverse measurement methods.

c. Mr. Brantley mentioned the Tellurometer used in Illinois was not as accurate on short distances as would be necessary for staking bridges for construction. However, it has been used to check the constructed length of bridge segments and entire bridges. Recently, Illinois procured a Geodimeter and used it to check the dimensions of as-built bridges, particularly the length of spans. Geodimeter measurements revealed the initial staking by survey methods employed on the ground had not been as accurate as initially anticipated.

11. Mr. Johnson said topographic maps photogrammetrically compiled at a scale of 40 ft to 1 in., containing contours on a 1-ft interval, are being used in Connecticut. The City of New Haven has embarked on a surveying and mapping program and is having the entire city mapped photogrammetrically. Topographic maps are to be compiled which may be used as media for design, recording cadastral data, and annotating all utilities.

12. George P. Katibah said California had purchased a new Keuffel and Esser Model 5020 stereoscopic plotter, manufactured to specifications of the California Division of Highways. Performance, thus far, has indicated the instrument satisfies all requirements. California ordered its second Auto-trol, Model 3900, for use with a double-projection stereoscopic plotter. In addition, two Auto-trol scalers, Model 3935, are used for measuring cross-section dimensions from the contours of topographic maps for computing preliminary design quantities.

Also, the California Division of Highways has received a Wild PUG-1 point transfer device. This device is a precision instrument with which the images of aerial photographs printed on glass plates, as transparencies, are examined stereoscopically and pass points and control points are marked for measuring bridging points and cadastral survey points with the Zeiss Stereoplanigraph.

Within the several districts of the Division, 10 Geodimeters are in use, one Model 4A, one Model 4B, and eight Models 4D. Another Geodimeter Model 4D is on order, which will be loaned on a temporary basis to each district when the Geodimeter assigned to it is in need of repair. Experience and successes in use of the Geodimeter developed a nucleus of people in California capable of repairing the instrument. Only under exceptional circumstances will it be necessary to return it to the manufacturer for repairs.

Within several of the districts of the California Division of Highways, the demand for scribing of topographic and other maps is rapidly increasing. Some contracts awarded to photogrammetric engineering firms require the compilation of maps in pencil on scribe coat material. Once compiled and accepted, these penciled manuscripts are sent to the districts which will use them. Employees of these districts then undertake the scribing. By this procedure, uniformity in map drafting quality is achieved within each district.

The California Division of Highways purchases all photography by contract. The basic and supplemental control is planned in the photogrammetric unit of the central office, which also prepares the base for map manuscripts containing plane coordinate grid lines on scale stable scribe coat material. Each district makes the essential ground control surveys according to plan. Both the control and the base manuscripts are furnished to the photogrammetric mapping firms.

Employees of the Division engaged in right-of-way appraisal and procurement prefer planimetric maps to topographic maps. Consequently, planimetry and other details are scribed and prints made. Afterward, the contours are scribed to complete he scribed manuscripts for reproduction as topographic maps to be used for design nd other purposes.

13. Mr. Arneson said the U. S. Forest Service has the Wild PUG-1 point transfer device, which is used for marking selected points on the photographic transparencies printed on glass. Such transparencies are used in the Zeiss Stereoplanigraph Model C8 for bridging and in the Kelsh double-projection instruments for topographic mapping.

The Forest Service cooperated with the International Society for Photogrammetry in the International Controlled Photogrammetric Experiment to test the ability and accuracy of the PUG-1 point transfer device.

Holes made with the PUG-1 in the emulsion on the glass plates are not large enough to let light through in double-projection instruments. Consequently, they are enlarged by drill. Consistency was achieved in making the holes approximately 60 μ in diameter. Whether or not accuracy was improved by use of these techniques is not yet known. Repeatability, however, was achieved. Each stereoscopic model can be reoriented precisely to the exact position of the unit setup after the holes have been drilled. Such could not be accomplished without their aid.

The Forest Service uses white scribe coat material instead of color material. A Leroy lettering set is used for scribing letters and numerals on the manuscript. The scribe sheets are backed with a black material before copying photogrammetrically; sharp negative copies are obtained. Positives can be made by contact printing processes using the scribed manuscripts.

a. Mr. Katibah said the California Division of Highways uses a white on rust color for its scribe coating material.

b. Mr. Brantley said the Illinois Division of Highways is also having map manuscripts scribed.

14. Dr. Konecny said the University of New Brunswick had photographed areas after large protruding rocks had been covered by snow. Results indicate photogrammetric delineation of snow-covered surfaces can be accurately accomplished. In fact, configurations can be more reliably identified after the rock has been covered with a mantle of snow. Also, contours delineated under such circumstances indicate the c-factor is improved. Evidently, there is a sharpening of detail achievable from snow which is not possible from natural rock colors.

Snowfall depths can be measured by photogrammetric methods, but variations may arise. Some of these variations could be caused by the uncertainty with which the original ground (before the snow fell) could be accurately delineated.

15. Mr. Nickell mentioned Missouri has five Kelsh double-projection instruments but does not have an auxiliary device, such as the Auto-trol or Electronic Coordinatograph and Recording System, for measuring and recording cross-sections. Missouri accomplishes all essential basic and supplemental control surveying required for photogrammetric compilation of maps. The State has one precision coordinatograph for plotting plane coordinate points to establish plane coordinate grid lines and to plot control points on the gridded map manuscripts. Geodimeters are used for making basic control surveys.

Aerial film negatives are about 0.004 in. thick. In aerial camera operation, some vacuum failures have been experienced. Consequently, the film may not always have been flat at the instant of exposure. In rural areas, topographic maps are compiled at a scale of 100 ft to 1 in. with a contour interval of 2 ft. In urban areas such maps are compiled at a scale of 50 ft to 1 in. with a contour interval of 1 ft. All highway design is accomplished by use of these maps.

16. Fred B. Bales said there is vital need for an economical and effective method of preparing controlled photographic mosaics. The Virginia Department of Highways has been experimenting with the orthophotoscope technique, as developed by the U. S. Geological Survey. These orthophotographs are used in the design of interchanges and the preparation of highway construction plans. They are especially useful in lieu of planimetric details. Data for rectification and for printing to scale the photographs to be used in compiling the mosaics are obtained from topographic maps.

a. John H. Wickham, Keuffel and Esser Co., said the Virginia Department of Highways has unique and efficient photographic and photogrammetric laboratories, second to none.

b. Mr. McNoldy concurred with Mr. Wickham and said he hopes Pennsylvania will be able to take advantage of the leadership and the efficiency achieved by Mr. Bales in planning, constructing, and equipping the photographic and photogrammetric laboratories of the Virginia Department of Highways.

c. Mr. Bales said photographic emulsion development chemicals are mixed in 55 gal lots. The chemicals, ready for use, are stored at the top of the building and flow to the laboratory by gravity.

17. Mr. Brantley said Illinois recently purchased a Geodimeter for daylight use in control surveying. Thus far, however, trouble has been encountered in maintaining an operating power supply. Illinois also purchased recently a new LogEtronic automatic dodging printer that is much faster and more efficient than the older model. Unfortunately, during the first use, a short circuit burned the internal operational equipment, requiring extensive repairs by the manufacturer.

Station markers of horizontal control have been established at an interval of approximately 3 mi along 350 mi of Interstate highways throughout the State. Bench marks along the same highways are set at intervals of about 1 mi. Accurate control surveying has been accomplished by the U. S. Coast and Geodetic Survey to establish the horizontal position and elevation of these markers.

Difficulty has been experienced wherever highway projects are separately designed and surveyed by different consultants. The difficulty usually occurs where the separate projects join, especially on tangents. Invariably, a "dog leg" seems to occur, although the tangent is supposed to be straight. The contiguous (continuous) tangent contains an angle at the point of juncture of the two projects.

a. Mr. Radmanovich remarked power failures were the principal cause of downtime for Geodimeters in California.

b. Mr. Habel commented each P.O.T. contains an angle, which should always be realized because each user of a surveying instrument will seldom achieve exact repeatability of backward and forward sighting on P.O.T.'s in extending a tangent line from PI to PI, as the extension is made through each successive P.O.T. Consequently the bearing of a tangent from PI to PI should govern and not the bearing from PI to P.O.T., P.O.T. to P.O.T., or P.O.T. to PI.

c. Mr. Watts said coordination of the work of separate survey parties, control computation engineers, and engineers accomplishing highway design (utilizing the precisely surveyed control and photogrammetrically compiled maps) will make it possible to achieve straight tangents on segments where separate projects are joined. The occurrence of dog legs in the contiguous segments of project joining tangents is merely an indication of lack of correlation between working groups.

d. Mr. Brantley said variations in azimuth continue to plague engineers and others concerned with right-of-way procurement. This is especially so when the property boundaries common the the separate descriptions of two adjoining parcels are not compared and checked to be sure they are identical in bearing and distance. Most discrepancies, of course, could be avoided by proper correlation and mathematical adjustment.

Large-scale topographic and other maps are scribed in Illinois. At bridge sites, the maps are compiled at a scale of 40 ft to 1 in. and then enlarged to a scale of 20 ft to 1 in. Scribing is especially effective for this process. Fine lines scribed at the scale of 40 ft to 1 in. are doubled in size at the scale of 20 ft to 1 in. but retain their uniformity and sharpness. After the maps are enlarged, the lines are not any wider than they would be if inked or scribed to a normal width and not enlarged.

18. Mr. Pryor reported briefly the development of an electronic photogrammetric measuring and mapping instrument, tentatively named the Omnistereomeasurer BPR. Work accomplished by 1960 proved the initial concepts were sound. Essentially, the instrument will eliminate projection lenses and optical trains. Any focal length and

format of photography, in black and white or color, can be utilized. Stereoscopic models being measured or mapped may be viewed at the instrument or at any remote location, wherever desired, by one or any number of persons in one location or in separate locations. Working drawings are being completed from which a prototype operational instrument may be constructed. The instrument system may be utilized for the compilation of planimetric and topographic maps, for measurement of profile and cross-sections, and for production of orthophotographs. Corrections will be made for lens distortions, changes in film negative dimensions, atmospheric refraction, and Earth curvature. The stereoscopic model may be examined at any scale desired. Maps may be delineated and profiles and cross-sections drawn at any practicable scale, because there is no limitation, excepting accuracy, on the ratio between photography scale and mapping scale.

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The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY-COUNCIL and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the BOARD are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.

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