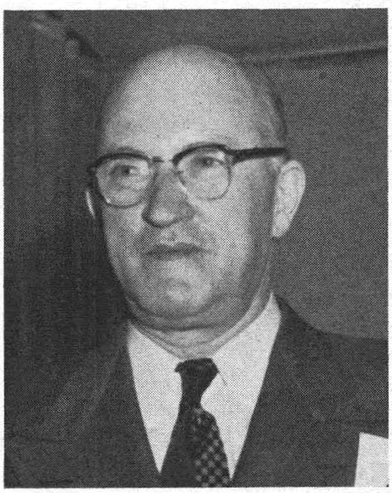
to authorities are not dependent on the field survey; the issuance of all permits is thereby expedited.

This method is believed to be an improvement in pipeline location procedure offering savings not so much in actual survey costs as in the more important fields of good route location, general co-ordination of the project and avoidance of construction delays affecting scheduled completion.

FOREST SERVICE PROCEDURE OF UTILIZING HIGH AND LOW ALTITUDE PHOTOGRAPHY IN ITS COMPANION-INSTRUMENT PHOTOGRAMMETRIC PROCEDURE*

J. E. King, Chief, Cartographic Section, Division of Engineering, U. S. Forest Service

FOR an understanding of the work of the U. S. Forest Service, particularly as it applies to photogrammetry, it is desirable to outline briefly its many responsibilities and interests that are vitally concerned in the application of the science of photogrammetry. It is strongly believed that the Forest Service, with its diverse activities, has probably profited more from photogrammetry than any other civilian agency.



J. E. KING

The U. S. Forest Service is responsible for the management of more than 180,000,000 acres; this amounts to approximately 10 per cent of the area of the continental United States. This involves the administration of 150 national forests located in 40 states, Alaska and Puerto Rico (Figure 1). The agency is faced with many management problems within this vast forest domain. Briefly some of them are: The prevention, detection and suppression of forest fires. Management of national forest timber, which includes inventory surveys, insect and disease control, timber stand improvement, and timber sales. Wide public use of national forests requires recreational planning, special use planning, mining claim adjustments, and the management of game and fish resources. To utilize grazing lands within the national forests, it is necessary to prepare range inventories for revegetation and resource conditions, and to plan and administer range allotments. There are also problems of land acquisition, land exchange and boundary surveys. Sound management of forest water resources requires the study and survey of dam and reservoir sites, irrigation layouts and power development. Travel within the forests requires the survey and construction of many thousands of miles of roads and trails.

Each of these operations, vital, not only to the Forest Service, but to the

* Paper read at Nineteenth Annual Meeting of the Society, Hotel Shoreham, Washington, D. C., January 14 to 16, 1953.

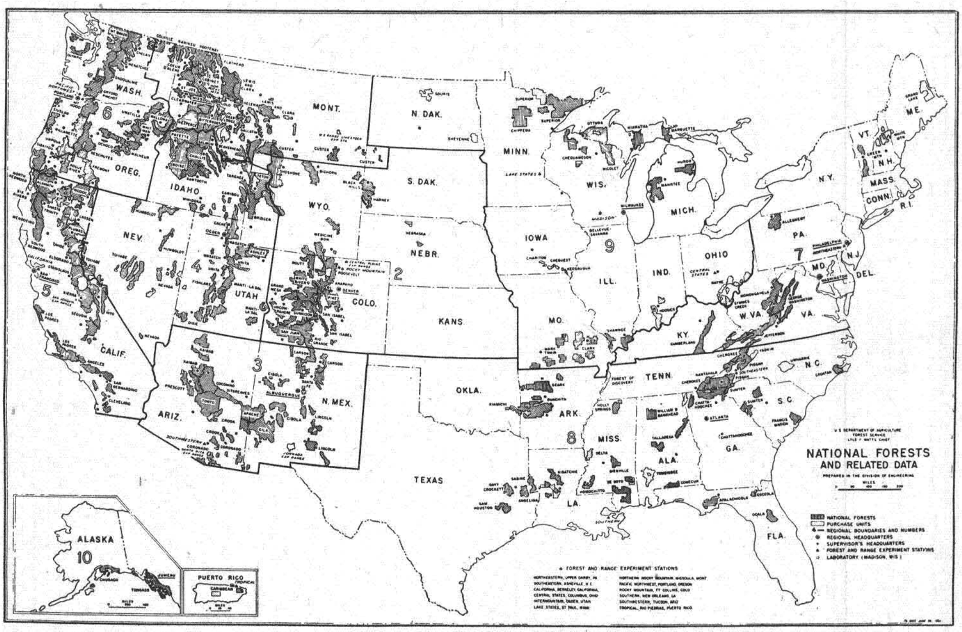


FIG. 1. National Forests in the United States and Possessions.

nation as well, is more efficiently and economically executed through the application of photogrammetry.

It should not be construed that the foregoing examples of the value and use of photogrammetry to the Forest Service are all inclusive, as time limitations prevent more detailed data. Consequently, there will be discussed in detail only the Forest Service procedure of utilizing high and low altitude photography in its companion-instrument photogrammetric procedure—the title of this paper.

The Forest Service makes no claim that the companion instrument and dual photographic idea is new. It is realized that several mapping procedures employing this principle have long been in use by our European neighbors. However, it is contended that the procedure used by the Forest Service is unique and original in its application, primarily due to the fact that high precision and economical performance is attained by utilizing readily obtainable photography and relatively inexpensive American-made stereoplotting equipment.

The development of this procedure was the result of several factors. First, as is often the case, the amount of appropriations to the Forest Service would not permit the purchase of expensive equipment; second, equipment was needed which would be capable of utilizing readily obtainable photography. As a consequence, the effort to economically

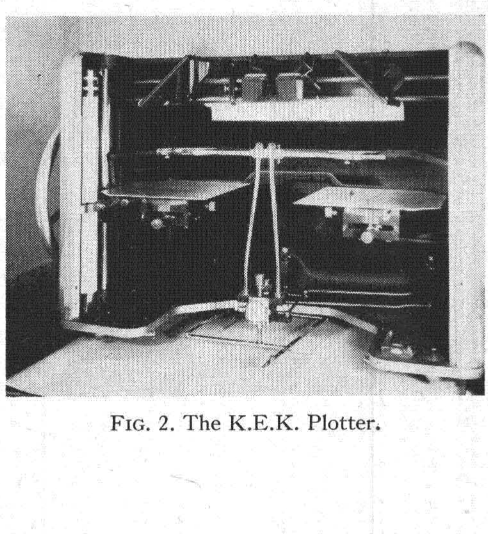


FIG. 2. The K.E.K. Plotter.

satisfy the ever-increasing needs of the Forest Service led to the development of the KEK Plotter in 1937 (Figure 2). This instrument served its purpose well, but did not solve the problem of serving the multiple management needs. It was quite obvious that a single purpose photograph or a specific type of map was definitely not the answer to over-all requirements of the Forest Service. Much thought and research were given to this problem, but equipment and facilities available greatly limited efforts to produce multiple-purpose maps that would completely serve all management needs.

It was not until 1946, with the advent of the Kelsh Plotter (Figure 3), that the economic solution of our cartographic problems could be foreseen. With the cooperation of Mr. Kelsh and the Geological Survey, a series of tests were made to determine whether this instrument was the missing link. The results of these tests proved conclusively that it was the answer. As a result, in 1947, the Forest Service devised a procedure and formulated a program to utilize *two scales of photographs* for its *cartographic* needs, namely: high-altitude, small-scale photography for control purposes and low altitude-larger scale photography for inventory and detail.

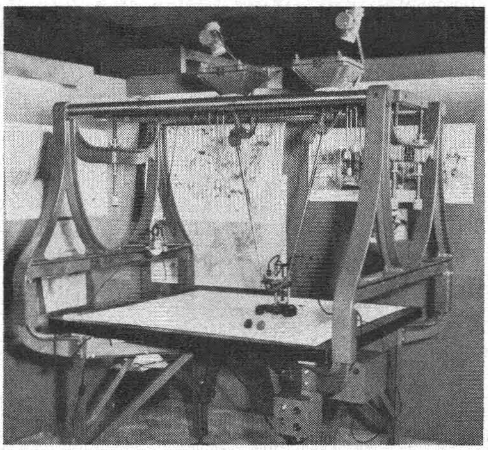


FIG. 3. The Kelsh Plotter.

Due to altitude ceilings and in order to prohibit restrictive bidding, it was decided that the small-scale photography would be obtained with a 6 inch metrogon lens at a scale of 1:40,000. This photography was to be used in the Kelsh Plotter primarily for horizontal and vertical control purposes only. The photography of the larger scale would be obtained with an $8\frac{1}{4}$ inch lens at a scale of 1:15,840 and would be used in the KEK Stereoscopic Plotter for map construction and detail purposes.

In carrying out this procedure the material is utilized in the following manner:

Immediately upon acceptance of the small-scale photography and before any use is made of the negatives, diapositives are prepared for use in the Kelsh Plotter; these plates are carefully stored for future use. The film is then available for any subsequent need, one of the first of which is the preparation of contact prints to be used in the construction of planning sheets. These sheets are simply bases for planning and the construction of planimetric maps; prepared by conventional photogrammetric methods by use of the KEK Plotter; portraying all planimetric detail discernible on the 1:40,000 photography. They are prepared in 15 minute quadrangle units at a scale of 1:31,680, and are required to conform to an accuracy of 1/12 inch at manuscript scale (Figure 4).

The contact prints are first utilized for the purpose of identification of existing horizontal control; this is to be the basic data for the construction of the planning sheets.

After a planning sheet is constructed it serves in two ways. (1) At the Forest Service regional offices and with field completion and the addition of land net and nomenclature, the planning sheet is converted into a planimetric map at the planning sheet scale (Figure 5). This map serves many needs. It is used for timber and grazing inventories, land classification, wildlife and watershed

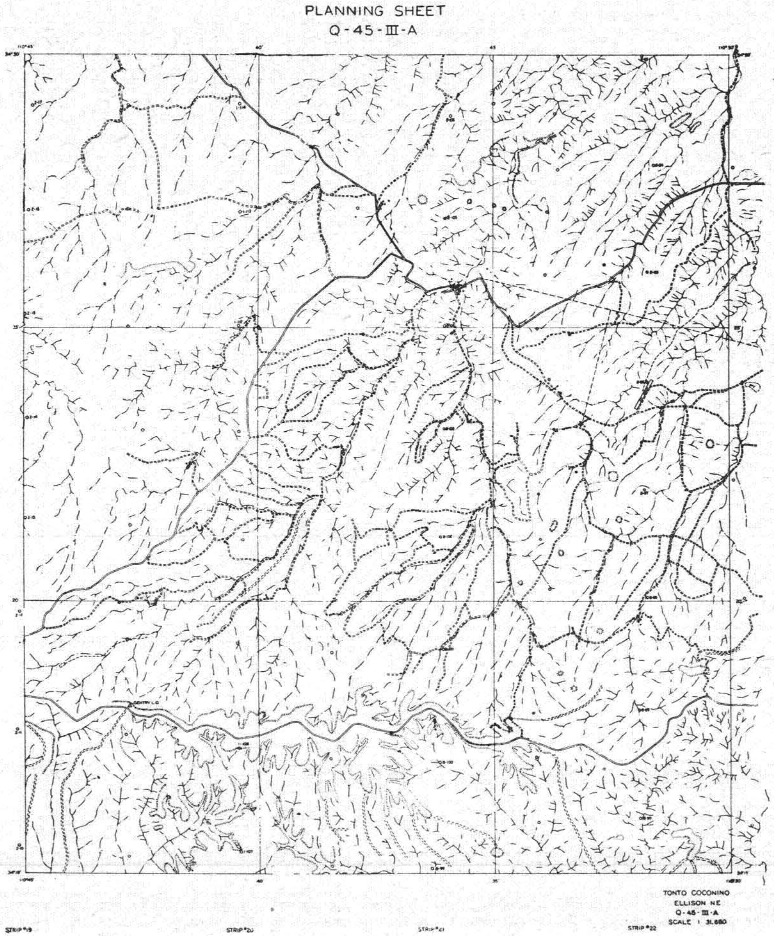


FIG. 4. Planning Sheet (15′ Quadrangle, scale 1:31,680).

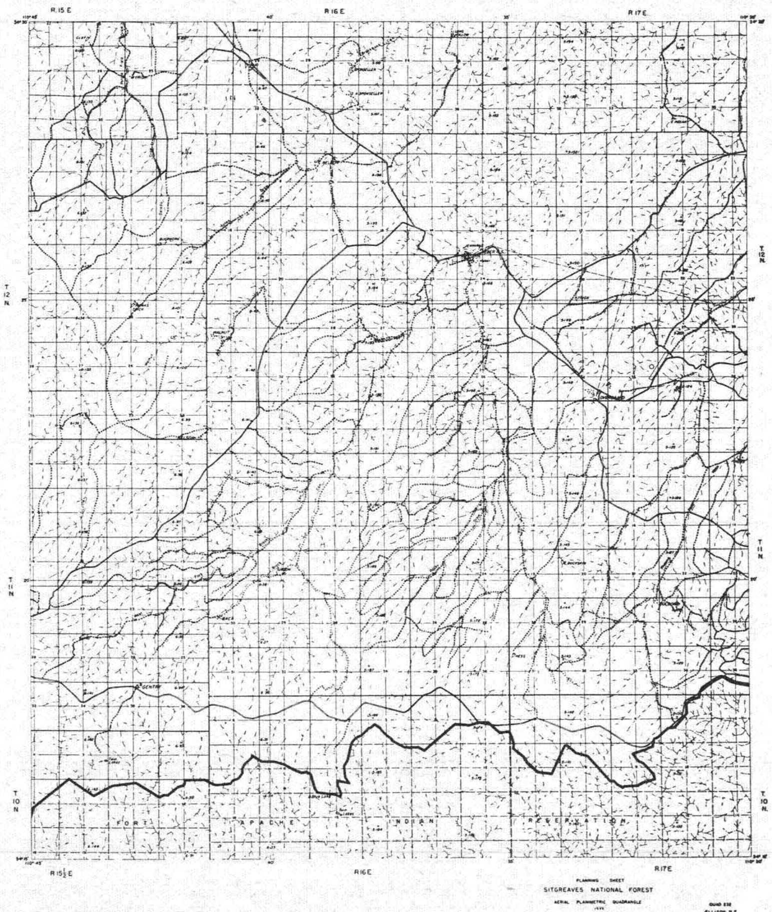


FIG. 5. Planimetric Map (15′ Quadrangle, scale 1:31,680).

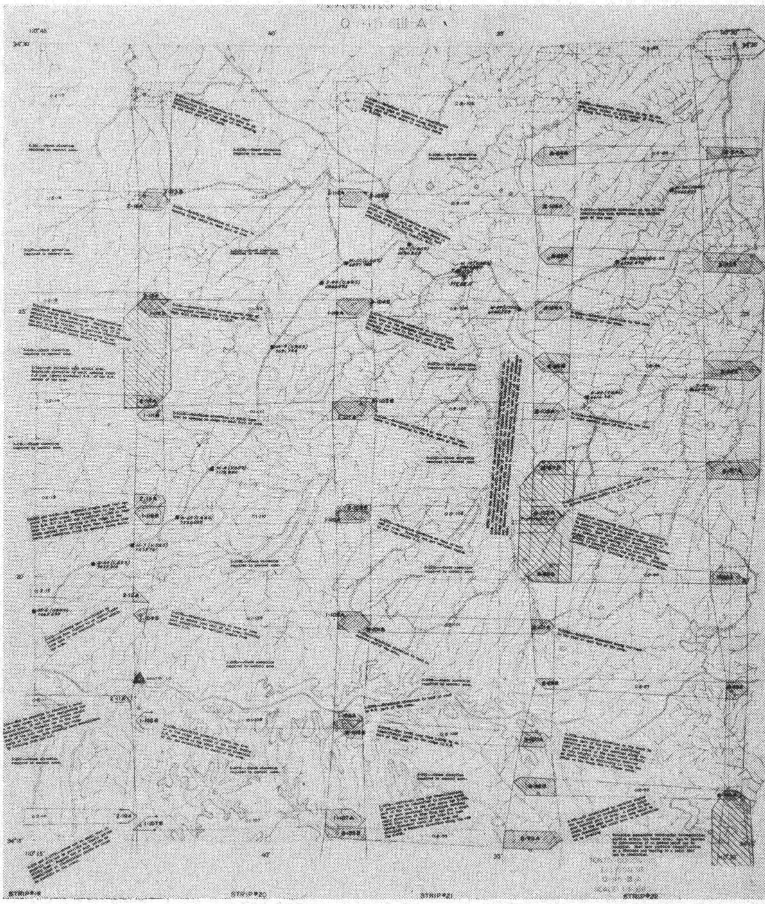


FIG. 6. Planning Sheet with Control Requirements for Topographic Mapping Indicated.

studies. In addition, it becomes the manuscript for the basic series administrative maps from which all national forest, ranger district, state and regional maps are developed on scales ranging from $\frac{1}{4}$ inch to 1 inch to the mile. (2) The second service is as a base upon which is planned all control required for the construction of standard topographic maps (Figure 6). The sheets, showing the control needs are forwarded to the regional offices as rapidly as completed, so that they may be available in guiding the establishment of horizontal and vertical control points in areas where topographic maps are required.

This planning sheet product enables the Forest Service to take advantage of any control extended by other agencies and eliminates overlapping and unnecessary control activities in the respective areas.

The extent of Forest Service topographic mapping operations is dependent upon the regional cartographic needs, and the sequence of operations is determined from individual regional priorities. All control operations are performed in accordance with the requirements indicated on the planning sheets, which, as a general rule, will require approximately 12 elevations and one 3rd or higher order horizontal control point for each $7\frac{1}{2}$ minute quadrangle. The geophysical characteristics of the national forests are such that the establishment of horizontal control is usually by triangulation methods. Accordingly, vertical control

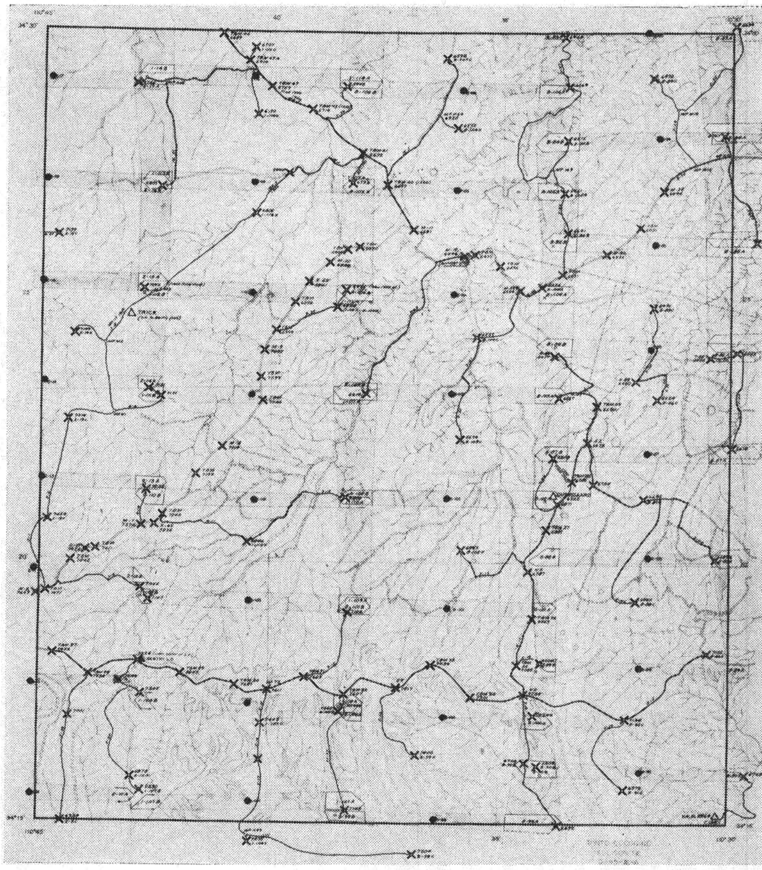


FIG. 7. Diagrammatic Work Sheet Showing Control Data Used in Kelsh Plotter.

is usually established by trigonometric leveling expanded from high order level nets. All of the foregoing field control operations are strictly the responsibility of the several regional offices, and are conducted by their field going personnel. All ensuing operations in the construction of the topographic maps are performed in the Forest Service Central Cartographic Section located in Alexandria, Virginia.

Upon completion of the field survey operations, the resulting data are transmitted to the Central Cartographic Section, where the material is utilized in the following manner:

Normal computation procedures are performed. A complete diagrammatic work sheet, showing all control data to be used in the Kelsh Plotter, is prepared on a print of the planning sheet (Figure 7). The establishment of supplemental horizontal and vertical control is performed by use of the Kelsh Plotter. Using the control data obtained in the field, stereo-templets are prepared for use in the radial plot to establish the additional horizontal control needed in the KEK Plotter operations. The number of points required will of course depend upon the scale of photography used in the KEK Plotter. Normally an average of 70 points for a $7\frac{1}{2}$ minute quadrangle is required. These templets are, so to speak, rectified templets, since they are prepared from stereo models at true scale; they may be termed half-templets as the stereo-model is the unit involved in

FIG. 8. Kelsh "Half-Templets" Being Laid.

their construction (Figure 8). The templets are made with the Kelsh Plotter at a 5 times enlargement, which, with the photography and equipment means a model scale of 1:8,000. They are then reduced, by precision mechanical means, to a manuscript scale of 1:20,000. The conventional slotted templet method is used for the extension of horizontal control, employing both heavy bristol board and sheet aluminum material. To facilitate control adjustment removable post studs are utilized in the radial plot.

Using the horizontal control thus established, in conjunction with elevations established in the field, makes it possible for the Kelsh Plotter operator to make absolute orientation for each model and to obtain the supplemental elevational points which are required to control the large-scale photography in the KEK Plotter.

As an indication of the accuracy obtainable with this procedure, the following example—an actual production result—is presented.

Photographic scale:1:50,000
Lens: 6 inch metrogon
Area: approximately 150 square miles on the Chanchelulla and Dubakalla quadrangles, Trinity National Forest, California
Elevation range: low, 1,219 ft. high, 5,857 ft.
Minimum elevation difference on individual model: 995 ft.
Maximum elevation difference on individual model: 2,494 ft.
Average elevation difference of all models: 1,793 ft.
Cover: varied from open to dense timber
Number of elevations checked: 110
Average deviation: 3.9 feet.

The number of supplemental elevations required is, of course, dependent upon the nature of the terrain. Usually, in the national forest areas, an average of 200 to 250 points per $7\frac{1}{2}$ minute quadrangle are established. It should be noted, however, that this is far in excess of minimum requirements for the KEK Plotter. Points are selected in the Kelsh Plotter which can be positively recovered in the KEK Plotter, and since such wide latitude is available in the Kelsh instrument for selection of these points, no attempt is made to restrict the number of elevations to minimum requirements; on the contrary, an effort is made to establish as many strategically located points as are necessary to insure the accuracy sought.

The procedure has now reached the point where the large scale photography is utilized. Inasmuch as the photographic requirements for Forest Service resource purposes are analogous to its cartographic needs, and since specifications require a manuscript scale of 1:20,000 with a contour interval of 10, 20 or 40 feet, photography of a scale of 1:15,840 is used in the topographic mapping operations.

Topography is drawn exclusively with the KEK Plotter. A brief description of this operation is as follows:

Contact prints on low-shrink water-proofed paper are prepared for use in the KEK Plotter. Manuscript bases, complete with projections and all field and office control, are prepared on metal mounted sheets, in $7\frac{1}{2}$ minute quadrangle units. These sheets, in conjunction with related data on the photographs, serve as the basis for absolute orientation of the stereoscopic models in the KEK Plotter. All planimetric and topographic detail is transcribed directly onto the manuscript.

This procedure has many advantages, one of the most outstanding being that the KEK topographer, whenever he encounters difficulties or is in need of additional control to insure accuracy requirements, can obtain additional control or control checks from the Kelsh Plotter at any point, at any time, and at a very minimum of additional time and cost.

For maximum detail the Forest Service requires a large-scale map accurately depicting all features. As a consequence, upon completion of the manuscript, blue line prints are prepared at the original scale, to serve as basic series maps for all engineering and management purposes. Essentially this base with planning sheet serves all Forest Service requirements and, in addition, results in a direct contribution to the National Mapping Program, since the original manuscript and related materials are delivered to the Geological Survey where field completion surveys, color separation, drafting and publication is accomplished.

In conclusion, there should be emphasized a most important over-all advantage of this procedure; it is conducive to a well planned long range program in which every dollar spent in any phase of operation is a direct contribution toward the end product and ultimate goal—the standard topographic map. It also eliminates duplication of cartographic effort, which in the past has been a costly weakness. Furthermore, it affords the forester, engineer, or administrator a readily available source of material from which he can obtain any pertinent cartographic data with minimum delay.

DISCUSSION OF PAPER—"FOREST SERVICE PROCEDURE OF UTILIZING HIGH AND LOW ALTITUDE PHOTOGRAPHY IN ITS COMPANION-INSTRUMENT PHOTOGRAMMETRIC PROCEDURE" BY J. E. KING

LEON T. ELIEL, Fairchild Aerial Surveys, Inc.* Mr. King's paper is very provocative and most interesting to photogrammetrists who take a more conventional approach to topographic problems.

Photogrammetrists with a background of using bridging equipment would be interested in studying the relative costs of the Forest Service method as outlined by Mr. King, versus the utilization of about one-tenth as much ground control, bridging with a machine such as the Wild A-5 or A-7, the Stereoplanigraph, the Poivilliers, or the Santoni, or—of course—the Multiplex; and then when the 1:40,000 pictures are in the machine for bridging purposes, record the tilt and swing data, subsequently replacing them to the corrected data computed from the bridge, and draw the finished map right from the 1:40,000 scale photography. The drawing could be done in any good machine, such as, for example, the Kelsh. The single requirement would be that it have a sufficiently high "*C*" factor to meet the accuracy requirements from 1:40,000 scale photography.

* Due to the absence of Mr. Eliel, his discussion was read by Victor Bellerue of the same company.

It sometimes seems as though the large initial capital investment of the big machines plays a disproportionate part in the thinking of our photogrammetrists. We know of one Stereoplanigraph which is still going strong after approximately 100,000 hours of operation. Thus the amortization charge against this machine has only been about 50¢ per hour. When consideration is given to how much less ground control these machines require, and also to other factors, a question is brought into very sharp focus, namely, why is it necessary to re-fly at a scale of 1:15,840 and stumble around amongst five times as many models as really have to be set up, if the 1:40,000 photography were used directly?

Is it possibly true that the Forest Service is building a big enough dam that they could use some 20-ton trucks to advantage in place of some of the little pick-ups it is employing?

MR. BELLERUE: My own comments on Mr. Eliel's last sentence—his reference to the trucks—are that I don't think he meant to throw out all of the pick-up trucks in the dam building business, because he has one or two, himself.

From my own experience, I feel in position to appreciate the tremendous contribution made by the KEK Plotter to photogrammetry and aerial mapping in bringing the entire Forest Service, in fact the entire forest industry, into photogrammetry. I feel able to appreciate because of having been in the position about ten years ago of having to produce two meter contour maps over an area of 3,000 square kilometers in South America, utilizing only two Fairchild Planigraphs. Consequently, I would like to be one of the first to express appreciation of the utility of the KEK. However, as Forest Service is now in big business, the time may be here or near when it should supplement the KEK with more elaborate machinery.

MR. KENDALL WOOD, Portland, Oregon: I would like to question Mr. King on what has been done, if anything, regarding the "hot spot" in six-inch photography which is common on the coast. Operations are made very difficult because part of the stereo model is obliterated.

MR. KING: You understand, I believe, that our six-inch photography is not used for detailed mapping. We have not entirely overcome the trouble caused by the hot spots in our photography. However, the photos are used for control purposes, only. We are dependent on the high altitude, the 1:40,000 photography, only on the areas in which we wish to establish control for the larger scale photographs. Therefore, we are able to work around any imperfections that may show up.

MR. WOOD: I would like to know whether in control photography you go to a lot greater side lap than ordinary. We have done that.

MR. KING: We have done that in some cases. But we have very rigid specifications and insist on complete compliance, as most of the contractors will know. But the required amount of overlap has not been in excess of that in normal photographic operations. We have been holding to the normal 55 or 60 per cent in line of flight, and 15 to 30 per cent side lap.

MR. KING (by letter):* Mr. Eliel's discussion of the Forest Service mapping procedure has developed an important point that the author neglected to mention in his explanation of the system. The large-scale photography employed

* This comment was received subsequent to the reading and discussion of the paper.—*Editor.*

for mapping purposes is obtained primarily for resource management activities and fire control planning. Thus, while small-scale photography might suffice for mapping, both scales are generally available to the Forest Service topographer with only the small-scale being charged to mapping.

In Forest Service mapping, moreover, it is seldom possible to take advantage of all the savings which may accrue from use of the more complex and expensive equipment in reducing the number of operations. The Forest Service depends upon resource management, fire control and similar funds to finance the mapping required in conjunction with those activities. The program is on a hand-to-mouth basis. So far, the ratio of available funds to the cost of meeting current demands has left no opportunity for the mappers to get out ahead. Hence, many scattered areas are mapped each year, each to the stage needed for the moment. For inventories, a planimetric map is often sufficient. Planimetric maps are also adequate in many instances for breaking timber areas up into working circles and ranges into allotments. As development becomes imminent, funds become available for the final stage of mapping and the topographic map is constructed.