STEREOTEMPLET TRIANGULATION*

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ABSTRACT

Stereotemplet triangulation is a photogrammetric method for establishing supplementary horizontal control positions. It differs from other techniques of radial triangulation in that the stereotemplet is representative of the horizontal plot of a stereoscopic model rather than a single photograph. The method permits the achievement of scale solutions by area and is not restricted to solutions of individual flight strips. The preparation of stereotemplets, options in their design and the techniques of their assembly are discussed. The advantages of the stereotemplet over the conventional slotted templet are stated. Several of the scale solutions achieved by the method are presented. It is shown that control requirements are less stringent for stereotemplet triangulation than for stereotriangulation.

TRIANGULATION with stereotemplets is a recently developed method for achieving the horizontal scale solutions required in photogrammetric mapping procedures.

A stereotemplet is a composite slotted templet mechanically representing the horizontal plot of a stereoscopic model. It is specifically designed for use in conjunction with stereoscopic plotting instruments and to utilize gainfully the advantages of the stereoplotting technique. Assemblies of stereotemplets were originally suggested in 1949 as a means of overcoming the horizontal bridging limitations of stereoscopic plotters that lack the facilities necessary to relate successive models to each other. The stereotemplet method combines the precision and geometric strength of the stereoplotting technique with a templet system that contributes the favorable qualities of an area solution. This method has been successfully used in areas where the flight pattern of the photography, the ruggedness and inaccessibility of the terrain, and the scarcity of existing horizontal control precluded the achievement of equally accurate solutions by other presently available techniques.

The positional data required for the preparation of the templet are stereoplotted from geometrically faithful optical models formed in the instruments. Positions of image points plotted orthographically from leveled models are rectified with respect to tilt and have no horizontal displacement due to relief. The positional data furnished to the stereotemplet is, therefore, at a random but uniform scale. The only function of the stereotemplet is to maintain this scale relationship between any and all points plotted from a single model while allowing for the enlargement or the reduction of the over-all scale of the templet. The stereotemplets are adjusted to the desired common scale when the templets are assembled to satisfy horizontal control positions.

The datum of a model from which a stereotemplet is to be prepared must be leveled to the tolerances necessary to maintain the proper planimetric relationships to positions plotted orthographically from the model. The stereoscopic model provides the operator with an excellent means of observing, comparing and measuring the elevations of physiographic features within the area. All stereoscopic plotters are equipped with the means of adjusting the model to a desired orientation. Where vertical control is available, the datum of the model may be quickly oriented to within one degree of a horizontal plane. In lieu of known elevations, hydrographic features such as swamps, lakes and major drainage provide information useful in eliminating the excessive tilt of a model datum. Where the photography has been flown in accordance with specifications that limit tilt and flight height variations, the spatial orientation of the projectors furnish data usable in limiting the inclination of the model. Where the tilt solution is questionable and the relief

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† At the Annual Meeting in 1955 Mr. Scher received the Fairchild Award because of his development of the stereotemplet method of triangulation.—*Editor.*

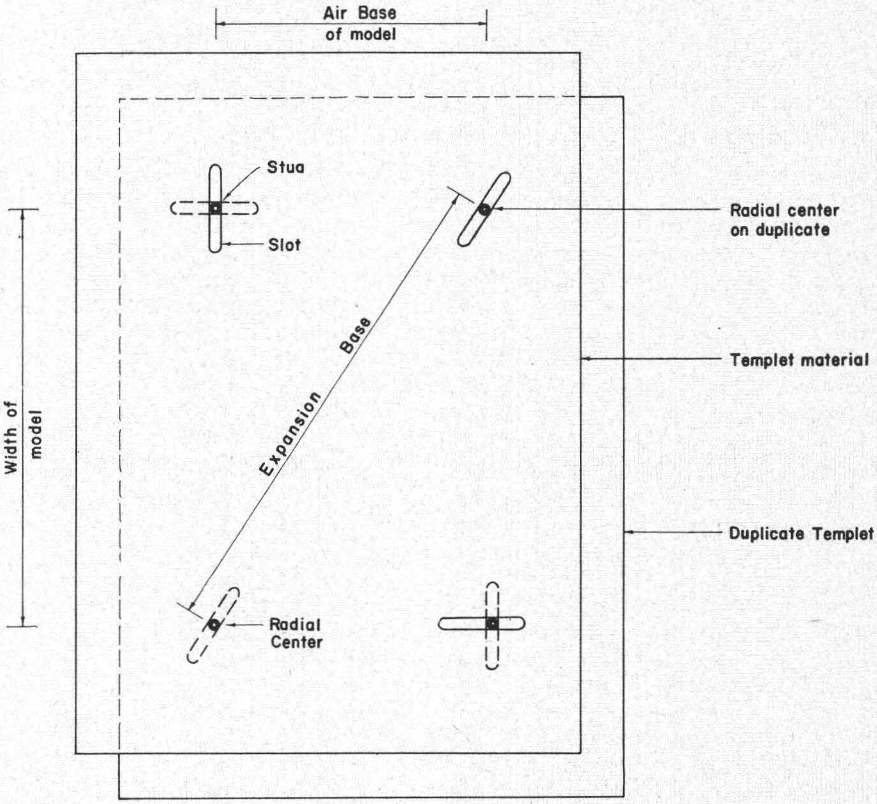

FIG. 1. Stereotemplet of a single stereoscopic model.

within the model area is extreme, possible errors of planimetric position are reduced in magnitude by the selection of pass-point images of approximately equal elevations. Where the existing conditions of terrain, photography and control are such that the orientation of many models is in doubt, the tolerances of allowable model tilt may be increased by decreasing the scale at which the templets are to be prepared and assembled. It should be recognized that for areas where this combination of adverse circumstances is apt to occur, a smaller scale map would be contemplated.

With the exception of the stereoscopic plotter, the equipment necessary for the preparation of stereotemplets is identical with that used to prepare conventional slotted templets. Hard pressed cardboard, .03″ thick, has the rigidity necessary to resist deformation and has proven to be a satisfactory templet material.

A stereotemplet, illustrated in Figure 1, is prepared by stereoplotting all relevant horizontal control and pre-selected pass-point positions onto the templet material. These positions are pricked through to another section of templet material to form a duplicate. Each templet will contain a minimum of four plotted positions, representing image points, in each of the four corners of the respective neat stereoscopic model. A stud-fitting hole is punched at one of these model corner positions. Stud-fitting slots, containing the other positions plotted from the model, are cut radially from the corner hole. In the duplicate section of the templet material the stud-fitting hole is punched at the position of the pass point representing the diagonally opposite corner of the model. Slots, containing the positions of all other points, are cut radially from this hole. The two sections of the templet are then identically oriented and one superimposed upon the other. Studs, that are to represent model image points, are placed through the holes and slots. This composite is referred to as a stereotemplet. The scale of the stereotemplet may be varied as

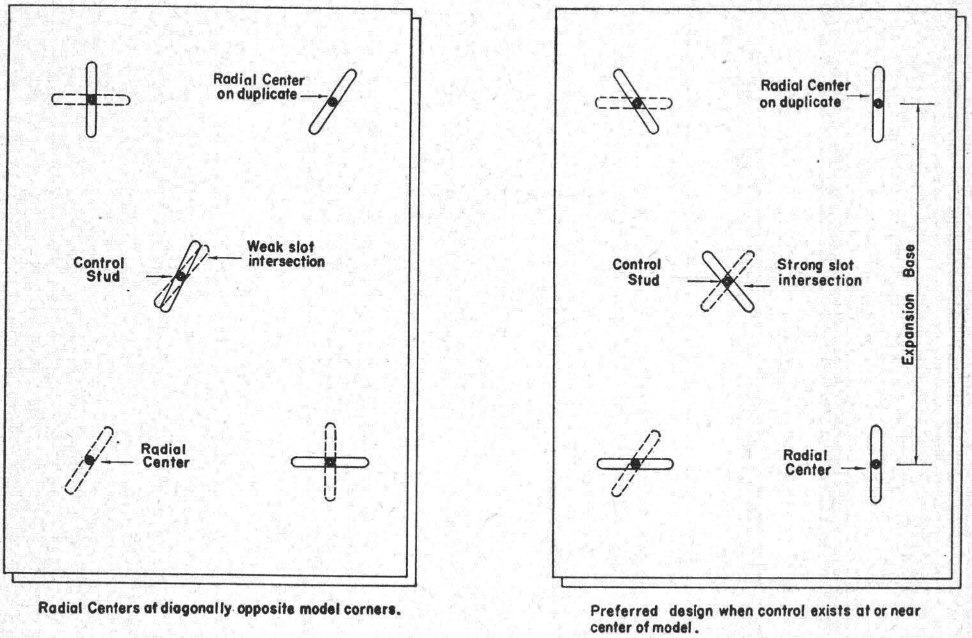

FIG. 2. Optional locations of radial centers.

needed. Each stud will move a proper proportional amount to satisfy any necessary scale change imparted to the stereotemplet.

The holes punched in each of the sections of the templet need not be diagonally opposite to each other. These are the preferred locations for the radial centers and provide the templet with its greatest strength. The left diagram of Figure 2 shows that when the position of a horizontal control point is plotted on or near a line connecting the two radial centers, the slots cut radially from these holes would define an ineffective angle. To assure a strong angle of intersection at the control point, one of the radial centers may, and should, be located at another of the corner positions, as shown in the right diagram of Figure 2.

The positions of the principal points of the exposures forming the model are not essential for the construction of the stereotemplet. However, it is advisable to include their positions on the templet when the images selected as pass points are not readily identifiable. The projected images of principal points that have been printed or etched on the diapositives are of certain identification. When included on the templets, these positions are not to serve as radial centers. As shown in Figure 3, their function is to provide a check on the exactness with which pass points common to successive models have been interpreted and plotted. Consistent identification of these pass points is verified when the two intersecting radial slots on each of the adjacent stereotemplets define a single position for their common principal point.

Figure 4 illustrates a stereotemplet prepared to represent the horizontal plot of two successive models as a single unit. Multiple-model stereotemplets have been used to advantage. Their preparation requires the use of a stereoscopic plotter capable of orienting adjacent models at a uniform scale. Their use is advised in areas where the lack of image detail prevents the selection of model-corner pass points common to adjacent models. Two or three model units are recommended as a means of increasing the physical size and strength of the templets. The representation of a long strip of models by a stereotemplet is not recommmended. This practice would replace the random errors of individually oriented models with the cumulative errors characteristic of stereotriangulation.

The accuracy of scale solutions that may be achieved with assemblies of stereotemplets is far greater than that anticipated

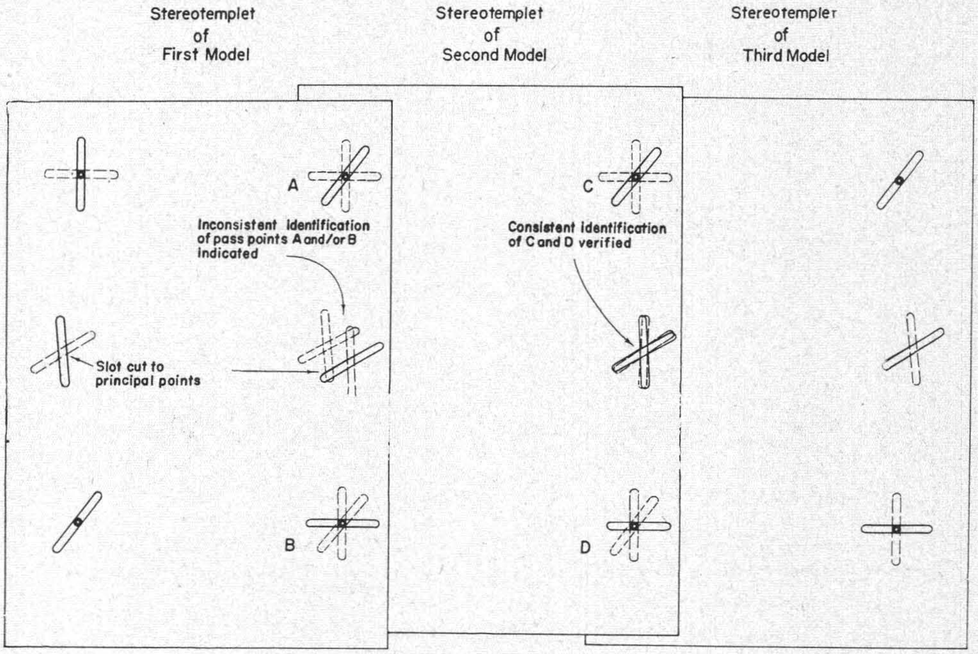

FIG. 3. Principal point check of passpoint identification.

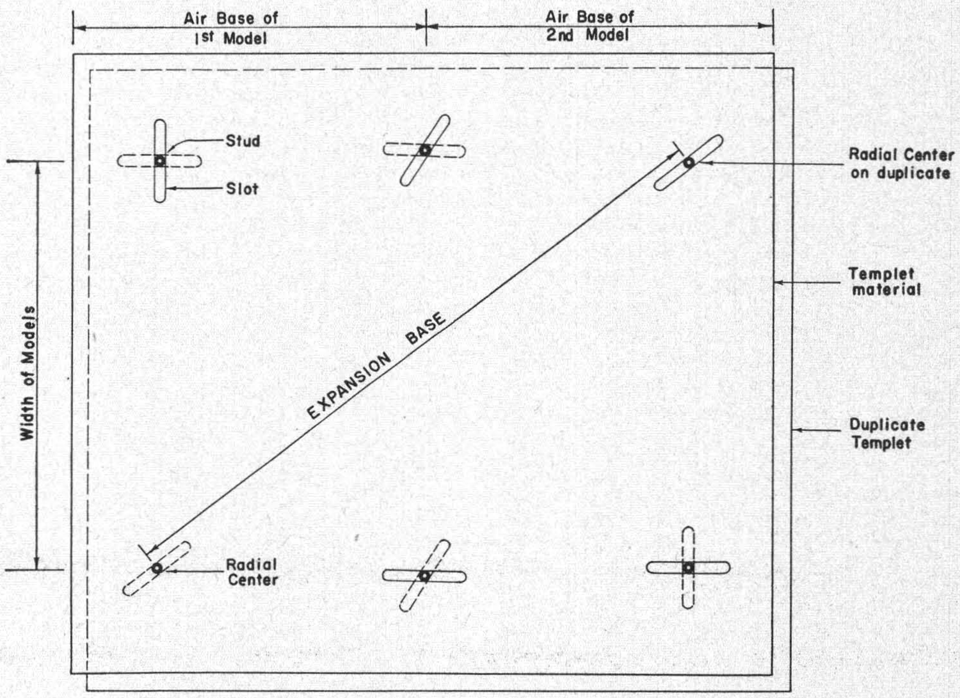

FIG. 4. Stereotemplet of two bridged models.

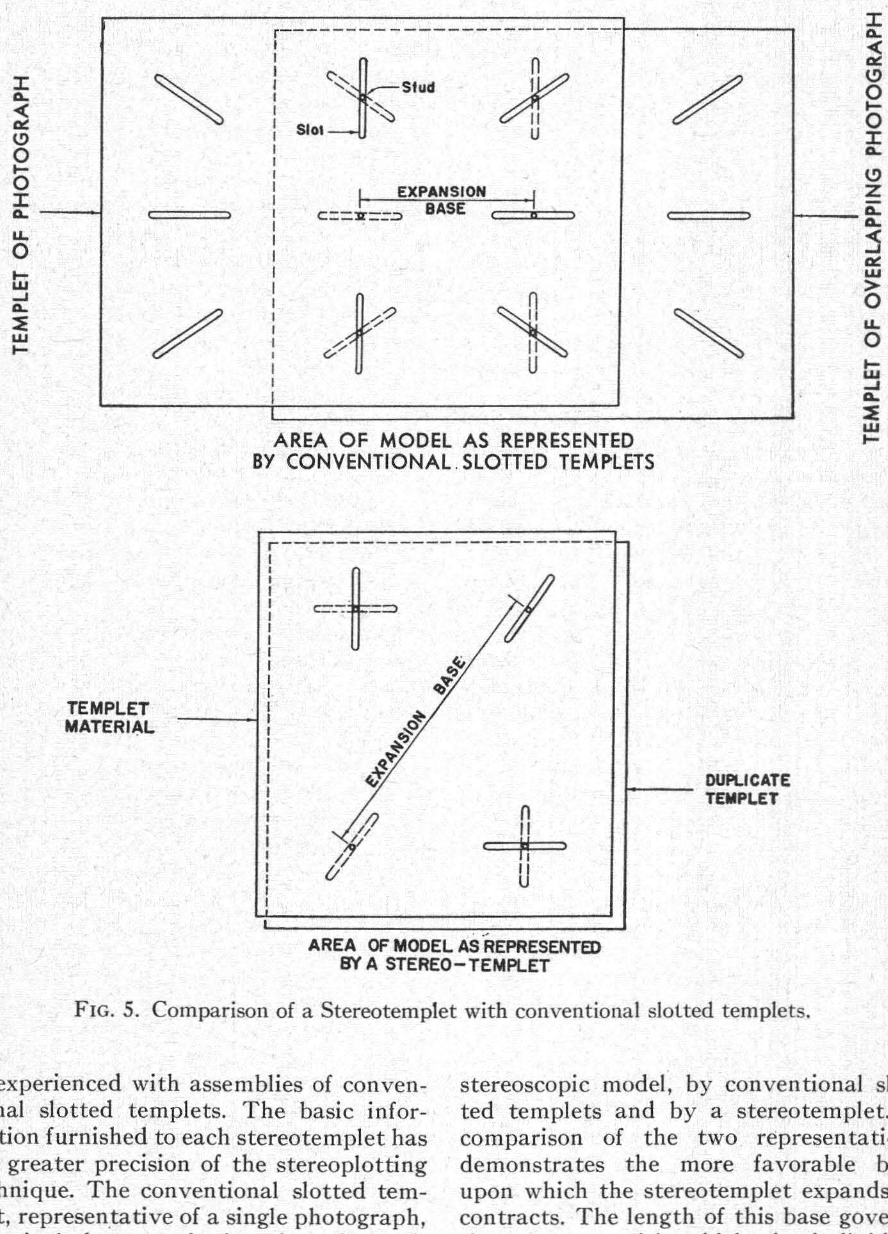

FIG. 5. Comparison of a Stereotemplet with conventional slotted templets.

or experienced with assemblies of conventional slotted templets. The basic information furnished to each stereotemplet has the greater precision of the stereoplotting technique. The conventional slotted templet, representative of a single photograph, must include among its functions the rectification of image displacements due to relief and tilt. This monoscopic consideration dictates that all slots be cut radially from a point at or near the center of the conventional templet. The elimination of rectification as a function of the stereotemplet permits its design to be stronger and more accurate.

The diagrams in Figure 5 are shown at the same scale and illustrate the representations of an area, included in a single stereoscopic model, by conventional slotted templets and by a stereotemplet. A comparison of the two representations demonstrates the more favorable base upon which the stereotemplet expands or contracts. The length of this base governs the accuracy with which the individual templets retain uniform scales while changing size. The diagrams also show the more advantageous angle of slot intersection inherent in the design of the stereotemplet. The positional information required for a stereotemplet may be limited to the data obtainable from one stereoscopic model. Stereotemplets permit the achievement of scale solutions in the direction perpendicular to the line of flight as accurately and conveniently as along the line of flight. They may be readily used to represent models formed from oblique photography.

Preparations for an assembly of stereotemplets are essentially the same as those required for a layout of the conventional slotted templets. A flat and rigid supporting base is necessary. Dyrite or stable manuscript paper sheets, securely fastened to the base, are satisfactory materials upon which to plot the necessary grid lines and horizontal control positions. The scale of the assembly should be equal to or larger than the intended compilation scale. Studs representing horizontal control points are secured to the base at their known coordinate values. To be of use in controlling the assembly, the images of these control points must be identifiable in the optical models and stereoplotted onto their respective templets.

The most effective pattern of the models to be used in an assembly is largely dependent upon the amount and location of the available control, and the size and shape of the project area. Where an abundance of control adds rigidity to the assembly, a considerable number of models within the area of interest may be eliminated. It is often feasible to omit intentionally models that might have an adverse influence on the scale solution. Models lacking evidence of proper level solutions and faulty models, indicating instances of camera failure or film instability, would fall in this category. It is desirable to include the templets of alternate flights completely and not to exclude any flight entirely. Where horizontal control is sparse, all models containing points of known position should be included. Where control at the perimeter of a project is lacking, the assembly may be strengthened by adding the stereotemplets of models adjacent to the area.

Personnel experienced in laying out conventional slotted templets are favorably impressed with the significant differences of behavior of stereotemplets during the process of assembly. The ability of the stereotemplets to retain scale and azimuth and to permit the extension of the scale in any direction facilitates the layout operation. Advantage of these qualities is taken by assembling the templets containing horizontal control first and then assembling the minimum number of templets that tie the control templets together. An immediate check of the reliability, the identification and the plotting of the available horizontal control as well as the proper preparation of the templets included in this network is provided. This procedure establishes early the size at which the remainder of the templets are to be assembled and thereby reduces their subsequent scale adjustment to a practical minimum. It is advisable to add the remaining templets in sequences that form successive square-shaped areas. When assembled in this manner, the stereotemplets are self-checking. A failure of templet closure is often indicative of an erroneous identification or plot of a pass point common to adjacent flights. An improperly prepared templet may be readily detected and replaced with a corrected templet. After the completion of the assembly, the determined pass-point positions are pricked through the studs to the dyrite or manuscript sheet.

The first two assemblies of stereotemplets were performed under conditions of control that were designed to satisfy the requirements of individual flight-strip bridging. In the earlier application the templets were prepared from Kelsh plotter models, reduced by pantograph to one-half the scale of the models and assembled at a scale of 1:15,840. In its second application the method achieved a scale solution for an area covered by low-oblique convergent photography. The positional data, at an approximate scale of 1:10,000, were plotted directly from models formed by appropriately tilted multiplex projectors. In both applications the results satisfied the standard map accuracy requirements of 1:24,000 scale publications.

A mapping project in Louisiana provided the first opportunity to apply the stereotemplet method in an area where the existing control was inadequate for the bridging of individual flight strips. A previous attempt to scale the area with conventional slotted templets had failed to meet accuracy requirements. The project, 350 square miles in area, included one and one-third 15-minute quadrangles and contained an abundance of control along its east and south edges. The western portion of the project area was sparsely controlled. Eight east-west flights of 6-inch photography flown at an altitude of 12,000 feet covered the area. One hundred and nineteen multi-

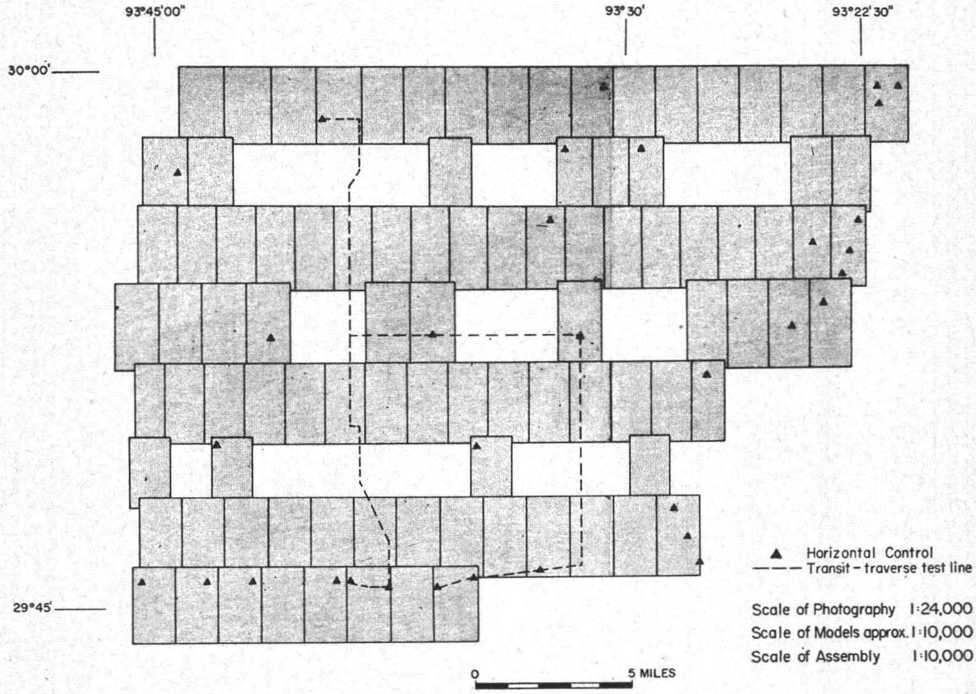

FIG. 6. Louisiana test—Stereotemplet assembly.

plex models provided complete stereo coverage. Figure 6 is a diagram of the 1:10,000 scale stereotemplet assembly and shows the relationship of the flights, models and available control. The longest flight contained 18 models and in the various flights, 1, 2, 3, 4 and 9 models were cantilevered beyond control. Twenty-six models, within the project area, were intentionally omitted from the assembly. Transit-traverse test lines, shown in the diagram as dashed lines, were run through what was considered to be the weakest areas of the solution. The field tests indicated that the positions determined by the assembly satisfied the horizontal accuracy requirements of 1:24,000 scale publications.

A most economical scale solution for a 15-minute quadrangle, straddling the Washington-Oregon boundary, was achieved with the use of high-altitude 6-inch photography, 10 existing horizontal control stations and stereotemplets prepared from Kelsh plotter models. Four models in each of four adjacent east-west flights of 1:72,000 scale photography provided actual stereo coverage for an area equivalent to 1.8 15-minute quadrangles. Figure 7 illustrates the pattern of the models and the location of the available control. A precision pantograph, adjusted to provide a two-time reduction, was used to reduce the data plotted from the Kelsh models to a scale of approximately 1:31,680. The assembly of the stereotemplets and the subsequent compilation of planimetric detail within the quadrangle were performed at a scale of 1:31,680. Field tests revealed a maximum horizontal error of 56 feet or approximately 1/50 of an inch at the scale of the stereotemplet assembly and the planimetric compilation.

Another application of high-altitude photography and stereotemplets provided a scale solution for an odd-shaped area including 24 $7\frac{1}{2}$-minute quadrangles and 23 existing control stations. The project area, called Zion Canyon, extends across the Utah-Arizona border and contains extreme and abrupt relief. Due to the lack of access roads in the area, field identification of the control was performed with the aid of a helicopter. Figure 8 shows the relationship of the available control to the 84 stereotemplets required to cover the

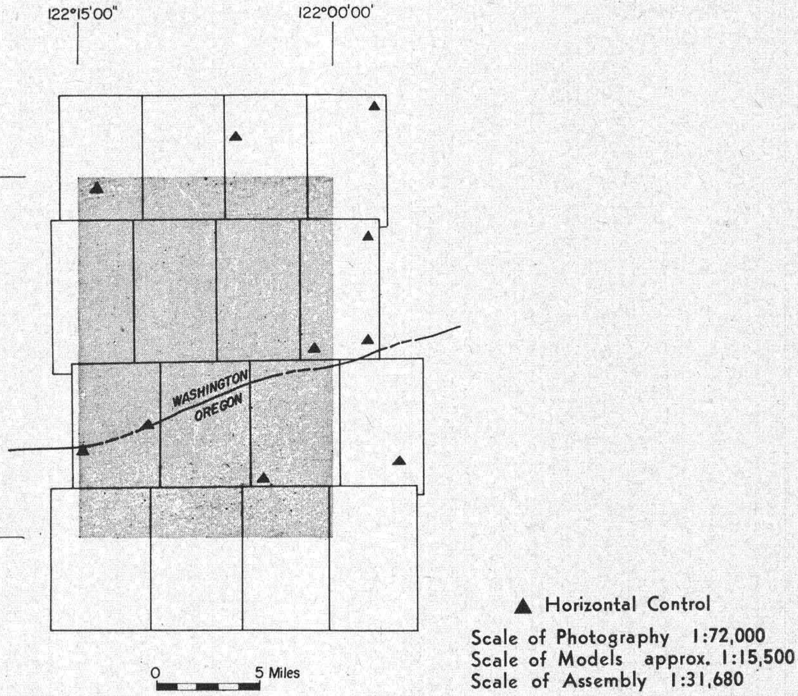

FIG. 7. Bridal veil—Stereotemplet assembly.

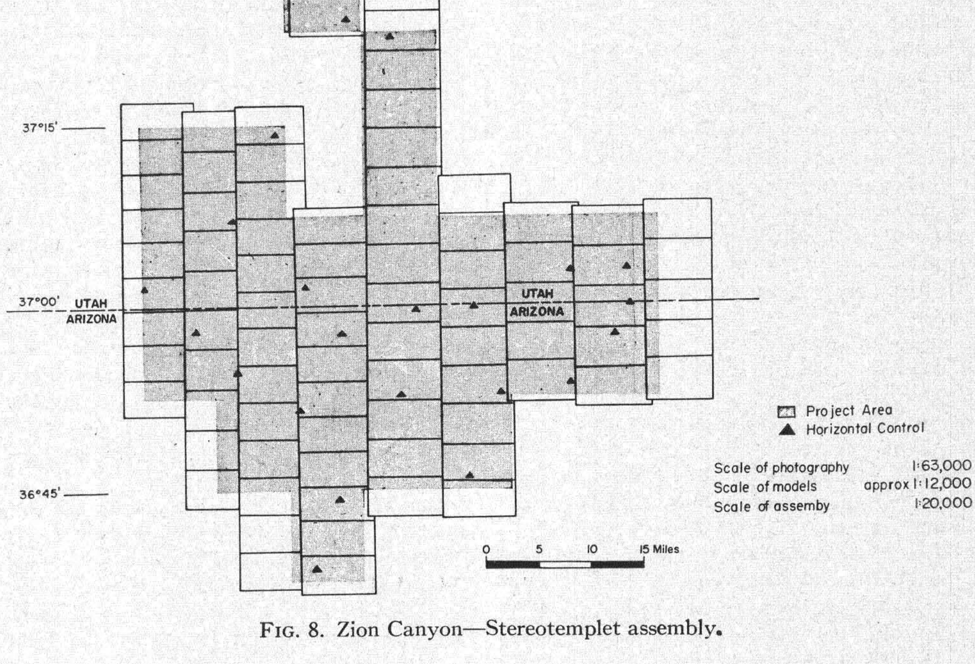

FIG. 8. Zion Canyon—Stereotemplet assembly.

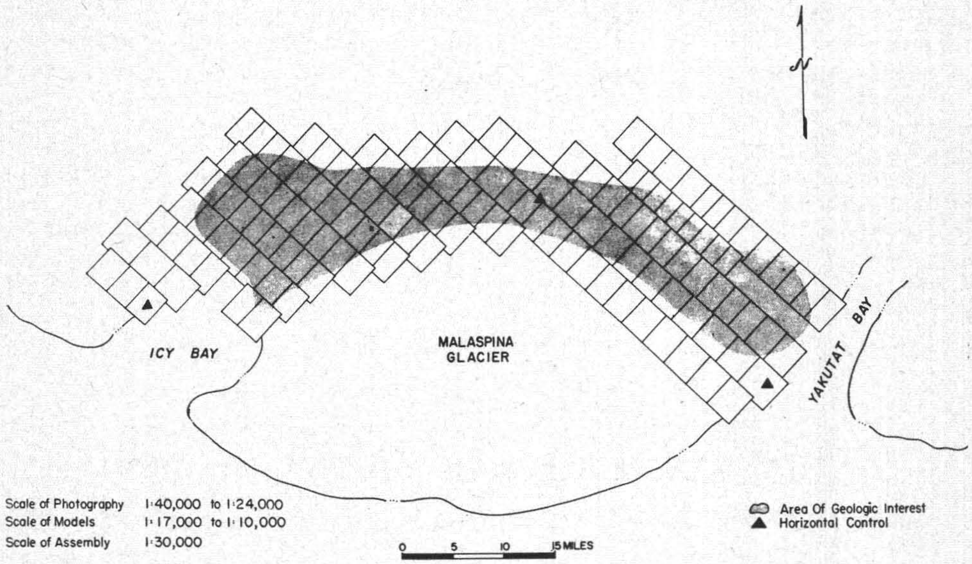

FIG. 9. Icy Bay—Stereotemplet assembly.

project area. The assembly was performed at a scale of 1:20,000. The templets were prepared at approximately that scale by pantograph reduction of the data plotted from Kelsh plotter models formed with 1:63,000 scale photography. Funds required for field testing the solution were not available. The expense would have been nearly equal to the cost of establishing the control required for stereotriangulation. A highly successful solution was indicated by the ease with which the templets assembled to control, the rigidity of the completed assembly, and the precision with which the positions of pass points could be recovered when the models were re-oriented for compilation purposes.

The geologic mapping of a large arc-shaped area, adjacent to and north of the Malaspina Glacier in Alaska, required the accomplishment of a scale solution under the most challenging conditions. The project, called Icy Bay, was covered by 6-inch photography flown by the Navy at a nearly consistent height of 20,000 feet above sea level. Figure 9 illustrates the relationship of the flights, the stereotemplets and the available control. Within the area of interest the elevation of the rugged and snow-covered terrain varied from sea level to approximately 8,000 feet. Only three points of known position could be photo-identified in the office with a sufficient degree of reliability to serve as control. One position, a well-defined peak located in the northern sector of the area, had been established from an International Boundary Commission Survey. Two U. S. Coast and Geodetic Survey stations, located near the shoreline, provided control at the east and west extremities of the assembly. Multiplex stereoplotting equipment was used. The scale of the models decreased from 1:10,000 to 1:17,000 as they approached the coast. The scale of the assembly was 1:30,000 and the stereotemplets were prepared at approximately that scale by appropriate pantograph reductions. To achieve a more uniform templet size, double-model stereotemplets were prepared in the higher areas. The area of interest, shaded in the diagram, was covered by 118 models. Forty-three additional stereotemplets were used to reach control and to strengthen the assembly. The templets connecting the north and east control points were assembled first. The east half of the assembly was then made rigid by adding the templets of the adjacent flights. The scale solution was then successfully extended, in a diagonal direction across eleven flight strips of photography, to the remaining control point.

The stereotemplet method has overcome many of the limitations inherent in the techniques that rely upon an independent scale solution for each of the pertinent flight strips. In an assembly of stereotemplets the influence of horizontal control positions is not confined to the particular flight in which they are located. Although the minimum control requirements for stereotemplet solutions are not presently established, it has been demonstrated that these needs are considerably reduced, both in amount and in location, from those required for stereotriangulation. In many areas where the existing control is not suitable for stereotriangulation, an adequate scale solution may be obtained with stereotemplets.

The method offers considerable flexibility in the use of available equipment and personnel. Any number and various kinds of stereoplotters may be used to prepare the templets for a project area. Stereotemplets provide a convenient means of combining into one simultaneous scale solution the positional information derived from photography taken at various altitudes, with cameras of different focal lengths and from vertical, low-oblique and high-oblique photography.

THE NEW AIR FORCE PHOTOALIDADE*

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ABSTRACT

This paper describes the operational characteristics and versatility of the USAF photoalidade designed for determining ground elevations from oblique photography of types being utilized in the compilation of aeronautical charts. In designing the new instrument, special consideration was given to great flexibility in format, focal length and depression angles encountered in photography used for charting. Charting with the photoalidade involves many techniques other than those of operating the instrument. A few of these techniques are briefly described.

THE new Air Force photoalidade is still in the developmental stages at the Wright Air Development Center. However, we have been using six of the experimental models in production work at the Aeronautical Chart and Information Center for the past two years.

Before specifically discussing the new Air Force model of the photoalidade, I will review briefly some of its history and development.

The photoalidade is an instrument which measures horizontal and vertical angles from photographs. The first instrument to measure horizontal and vertical angles from a photograph was designed before 1865 by a European named Porro. He called it the Photogoniometer.

Even though the photoalidade is similar to the later models of the European photogoniometer, its development in this country was independent of the European instrument. Development action before 1950 was restricted to the Geological Survey. About 1910, J. W. Bagley, a member of its staff doing reconnaissance mapping in Alaska, built a panoramic photoalidade to determine horizontal positions and elevations from panoramic photographs. With this instrument, he measured the horizontal angles to image points directly, but resorted to measuring vertical distances on the photograph in order to calculate the vertical angles and then elevations.

Nothing further was done in developing the photoalidade until 1932 when another Geological Survey man, Mr. R. M. Wilson, designed an instrument which would make possible obtaining horizontal and vertical angles directly and simultaneously. His instrument became known as the Wilson Photoalidade. It utilized a regular field theodolite in sighting on points in the photograph. The theodolite was so mounted that its center occupied the perspective center of the photograph mounted on the plate. Horizontal angles were supplied by the ruling blade which was rigidly attached to the spindle of the theodolite.

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