except that we will always tend to accept what we consider the superior solution for our purposes. Should a super wide-angle lens be produced which in our opinion performs satisfactorily as a lens, we will no doubt investigate its potential as a component of a mapping system and made an impartial comparison with other existing systems to determine whether it fills a Corps of Engineers need. There are too many questions to be answered on the use of a super wide-angle lens to permit one to arbitrarily state that such lens will make convergent photography obsolete.

To summarize, we are faced with a problem not common perhaps in Europe but common enough throughout the rest of the world, the problem being to map large areas previously unmapped or mapped poorly, at medium scales with a high degree of accuracy and with a minimum amount of time and expense. To solve such a problem we are investigating the combination of high altitude flying and convergent wide-angle photography. Our laboratory studies clearly indicate that contouring accuracy can be improved by as much as 100 per cent if convergent photography with a base to height ratio of 1.2 is used in place of the conventional vertical photography with a base to height ratio of 0.6. Our aero-triangulation tests have not been conclusive as yet; however we feel we can say that aero-triangulation can be accomplished with convergent photography with no less accuracy than vertical photography, and possibly greater accuracy. We are at present continuing our investigations and hope to make our findings available to the photogrammetric world through papers prepared by our scientists and engineers, to the extent possible in keeping with our policy of not making direct comparisons of competitive commercial equipment.

*Instrumentation for the Integrated Photogrammetric System of the U. S. Geological Survey**†

RUSSELL K. BEAN, *U. S. Geological Survey*

IMMEDIATELY after World War II a staff photogrammetry section was set up in the Topographic Division of the U. S. Geological Survey, with the prime objective of exploiting photogrammetry to its fullest through the medium of research. The attack on the problem was made simultaneously on three major fronts—aerial photography, photogrammetric instruments, and techniques and standards. Thus the concept of a "system" was evolved whereby all of the elements required to accomplish the goal of photogrammetrically compiling topographic maps more efficiently were considered as a unit, and the development work on any one element did not proceed until its effect on the system as a whole was determined.

A prime consideration was the basic geometry of aerial photography. For a

* This paper is a contribution to Commission II of the International Society of Photogrammetry.

† Publication authorized by Director, U. S. Geological Survey.

number of years it has been generally assumed that vertical aerial photography is the most efficient medium for topographic mapping. It has long been known, however, that twin low-oblique photography has certain inherent advantages which should lead to increased accuracy and economy in the cost of control and compilation of detail. Twin low-oblique photography has never been fully exploited because of the lack of suitable plotting instruments for using it, especially in the aero-triangulation phase. Most of the practical applications in the past have been confined to single models. It was obvious, therefore, that one of the first goals was to develop a satisfactory plotter for both horizontal and vertical aerotriangulation of twin photography. This objective was achieved in the Twinplex plotter (described below) and the way was opened for a complete twin low-oblique photography system for precise map compilation. Having accomplished this goal, there was immediately undertaken a complete investigation of all of the photogrammetric processes to determine wherein improvements could be made. Thus, a "new look" in photogrammetric instruments was developed at the U. S. Geological Survey. The following glimpses of the major items in our new look may be of interest:[1]

1. NEW LENSES AND CAMERAS

The recent development of new cameras, possessing greatly improved mechanical characteristics and equipped with high-resolution, low-distortion lenses, opens the way for improvement in both the photographic and geometric qualities of aerial photography. In order to obtain the maximum benefit from these improvements in camera characteristics, the Geological Survey has purchased a number of T-12 cameras (See Figure 1) equipped with Planigon lenses (based on the Topogon V designed by Herr Richter of Zeiss), for allotment to contractors on Geological Survey aerial photography projects. These cameras have been modified by the manufacturer to incorporate certain desirable features, such as additional fiducial marks and a device which indicates vacuum failure at the platen, thereby making the resultant photography more efficient for mapping purposes.

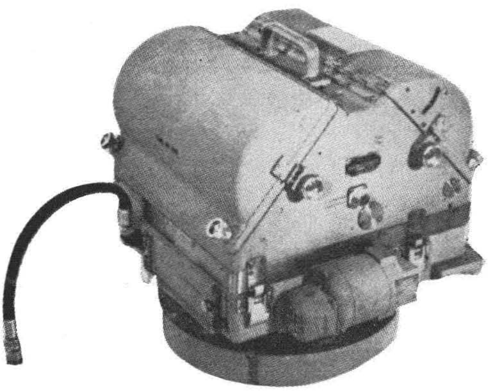

FIG. 1. T-12 aerial camera.

2. MULTI-COLLIMATOR CAMERA CALIBRATOR

As a further step in controlling the characteristics of cameras used on Geological Survey projects, the Survey has installed a multi-collimator camera calibrator (See Figure 2), by means of which cameras belonging to either the Geological Survey or private contractors can be quickly and carefully tested with a minimum of lost time. The unique feature of this calibrator is that it permits stereoscopic measurements of the test plates, thereby refining the procedure for evaluating camera performance.

[1] Investigations were also made into non-instrumental aspects of the photogrammetric system, such as further studies of the geometry of aerial photography, the effect of lens distortions, C-factor analyses, and other procedural studies. While important, they will not be discussed herein because they are not within the scope of this paper.

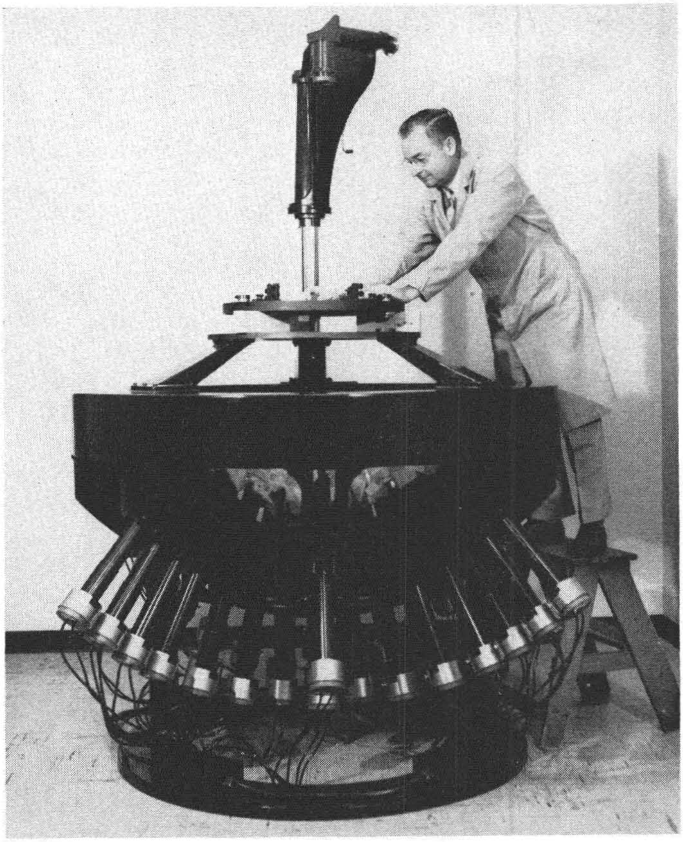

FIG. 2. Multi-collimator camera calibrator.

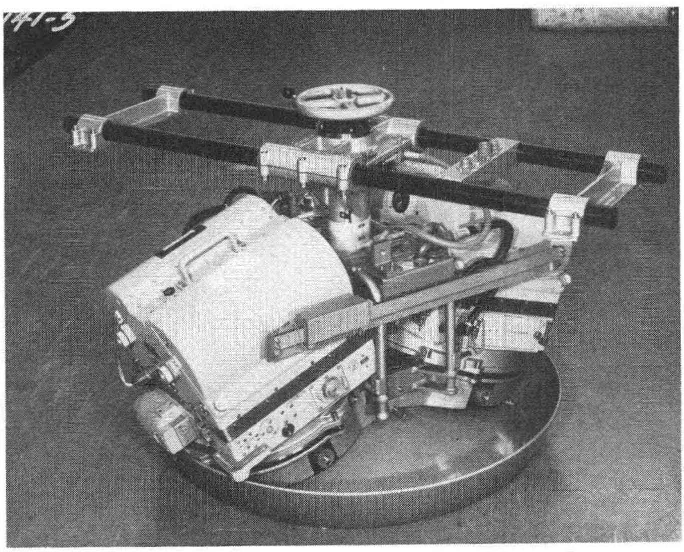

FIG. 3. Twin-camera mount.

3. CAMERA MOUNTS

A corollary problem arising from the use of twin low-oblique photography was the necessity of developing a mount (See Figure 3) suitable for obtaining this kind of photography. A satisfactory mount was designed by the Geological Survey and procured in quantity lots. The design, which incorporates a center-of-gravity suspension for the twin cameras, provides for maximum resolution by minimizing the effect of angular vibrations and accelerations.

4. TWINPLEX PLOTTER

As mentioned above, the success of a complete system for twin low-oblique photography requires a suitable stereoscopic instrument with which to accomplish aerotriangulation, both horizontal and vertical, using a minimum of field control. Such an instrument is the Twinplex plotter (See Figure 4), designed and developed by the Geological Survey for use with convergent and transverse twin coverage. Equipped with ER-55 projectors, the Twinplex is of such design and mechanical precision that the twin exposures from a single camera station can be treated as a single photograph, but with added strength, particularly in control extensions. The Twinplex plotter is now in operational

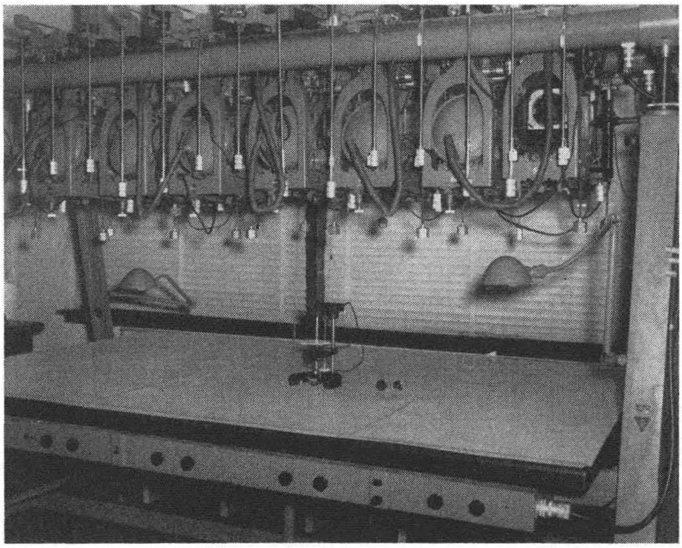

FIG. 4. Twinplex plotter with projectors oriented for transverse photography.

use as one of the key instruments in the integrated system of compiling maps from twin photography.

5. ER-55 PROJECTORS

The ER-55 projector, designed to be used with either vertical or twin low-oblique photography, is based on the principle that light emanating from a lamp placed at one focus of a prolate ellipsoid and reflected from the ellipsoidal surface will pass through the projection lens placed at the other focus (See Figure 5). ER-55 projectors can be used with vertical photography for either compilation or aero-triangulation. The adaptation from vertical to twin low-oblique photography is readily accomplished by a 20-degree step-tilt adjustment of the projector in its support, and rotation of the lens axis to satisfy the Scheimpflug condition. ER-55 projectors used in the Twinplex plotter, as already mentioned,

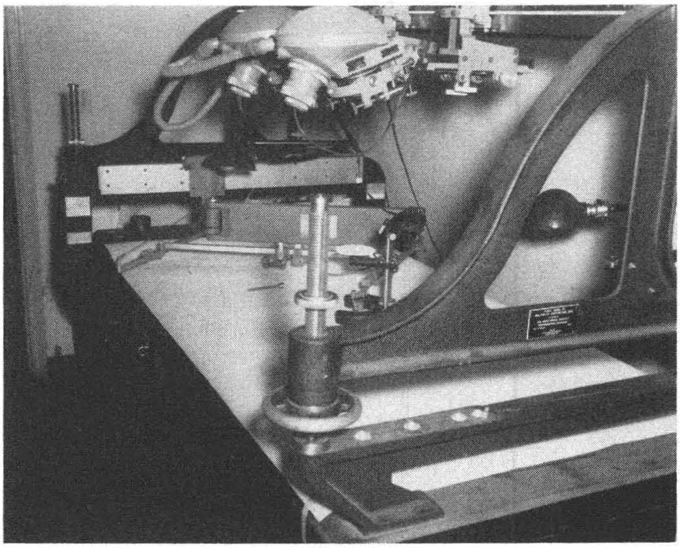

FIG. 5. ER-55 projector set up for transverse photography.

provide efficient and brilliant illumination of twin low-oblique photography used for aerotriangulation.

6. ASPHERIC PLATE DIAPOSITIVE PRINTERS

One of the primary problems in connection with printing diapositive plates is the method used for compensating aerial-camera lens distortion. The Geological Survey's solution in the case of Multiplex diapositive printers consisted of using a printer lens having, as nearly as possible, an equal and opposite distortion pattern to that of the aerial camera lens. The difficulty with this kind of solution is that unless the aerial camera lens and the printer lens are in close agreement with respect to distortion characteristics, there will be residual errors. The same situation arises in the use of the Kelsh plotter if the diapositives are made by contact printing, and the distortion is compensated by the use of cams which vary the principal distance of the projector in accordance with the location in the model of the detail being plotted. Unless the cams are matched precisely to the lens distortion pattern, there will be residual errors from this source.

The new approach by the Geological Survey was to develop high-resolution printers utilizing aspheric correction plates for compensating aerial-camera distortion (See Figure 6). Negotiations for such a printer were started in 1948. A set of correction plates having varying corrections in accordance with the range of variations in camera lenses of a given type provides a means of matching the printer compensation with the aerial-camera distortion more closely. The Geological Survey has designed and procured new-type projection diapositive printers of this nature for use with ER-55 projectors, Kelsh plotters, and Multiplex projectors. The printer for the Kelsh plotter, being one-to-one, can be used with other plotters using full-size diapositives.

7. VARIABLE-RATIO PANTOGRAPHS

In order to effect economies in the stereocompilation phase, a recent development of the Geological Survey has been the introduction of stereocompilation procedures involving scribing techniques and compilation work at scales at or

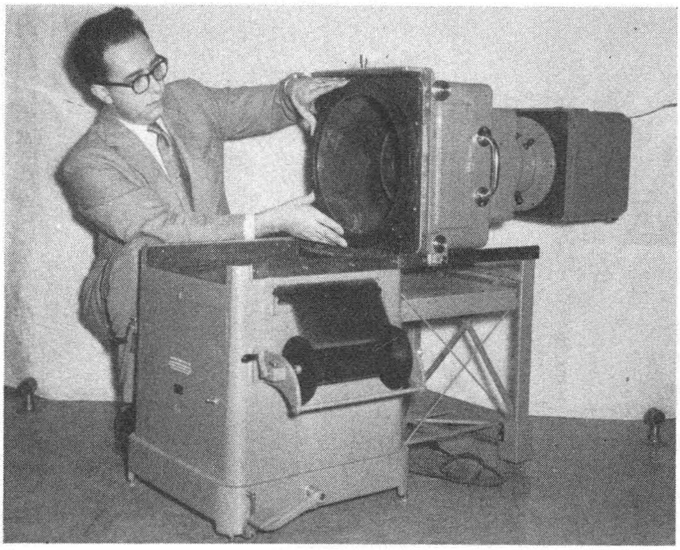

FIG. 6. Aspheric-plate diapositive printer, 153/153 showing location of aspheric plate.

close to the publication scale. The key problem in instituting these procedures has been the production of an efficient variable-ratio pantograph having the required degree of accuracy (See Figure 7). This problem has been one of considerable difficulty; however, the problem has been solved and a variable-ratio pantograph of the highest quality has been engineered and is now in production. The reduction ratio that can be obtained with the latest model is continuously variable from 1.45 to 1 to 6.5 to 1.

8. ORTHOPHOTOSCOPE

At the same time that work was progressing on instruments for the integrated system, investigations were made into photogrammetric instrumentation

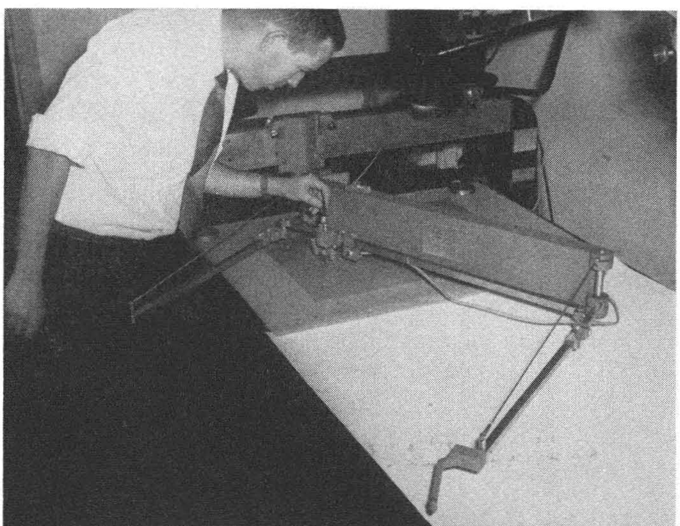

FIG. 7. Variable-ratio pantograph.

for photogeologic needs. These studies resulted in the development of the Orthophotoscope, a device for converting conventional perspective photographs to the equivalent of orthographic photographs. The photographs produced with this instrument are practically free of displacements of images due to tilt or relief, so that horizontal distances can be measured accurately on them (See Figure 8). Such uniform-scale photographs have many important uses in mapping, engineering, geology, forestry, and other scientific and military fields. The

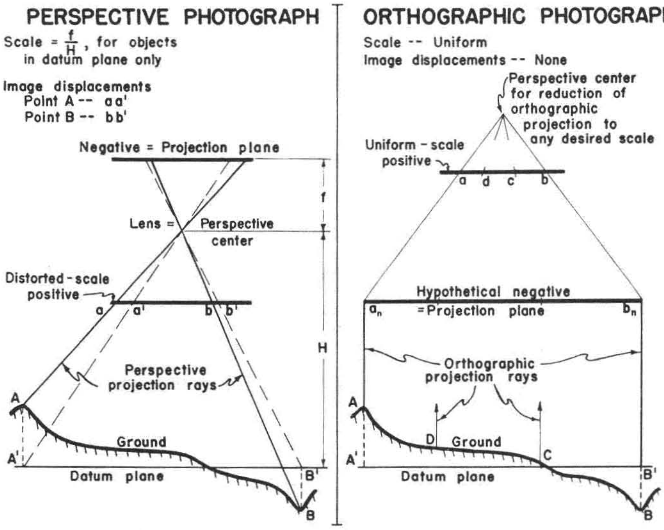

Figure 8. Comparison of perspective and orthographic photographs, showing effect of relief.

FIG. 8. Comparison of perspective and orthographic photographs, showing effect of relief.

new instrument is operated in conjunction with an oriented model formed by any type of double-projection stereoscopic plotter using the anaglyphic principle. A sensitized film is "scanned" by a slit in a screen on which the model is projected. The elevation of the film is varied according to the terrain as the scanning proceeds. The sensitized surface is film which is sensitive only to the blue light and not to the red light of the usual anaglyphic projection. When the scanning is complete, the film is developed as a negative and the "orthophotographs" are printed from this negative in any quantity or scale.

9. STEREOTEMPLETS

Another U. S. Geological Survey development, although not strictly instrumental, is stereotemplets, a new and highly effective means of radial triangulation of horizontal control. In this technique, the templets are obtained through the use of stereoscopic-plotting instruments. The basic data for these stereotemplets are derived stereoscopically from spatial models formed by the plotters, rather than from individual photographs. Because the model datum is approximately level and the photogrammetric control points are located orthographically on the templet sheet, displacements due to tilt or relief are virtually eliminated. It is therefore only necessary to provide a means of adjusting the scale of the templet assembly. This is done by making two templets for each model and using opposite corner points as centers of radiation, as shown in Figure 9. The scale may be readily changed by shifting the templets along the azi-

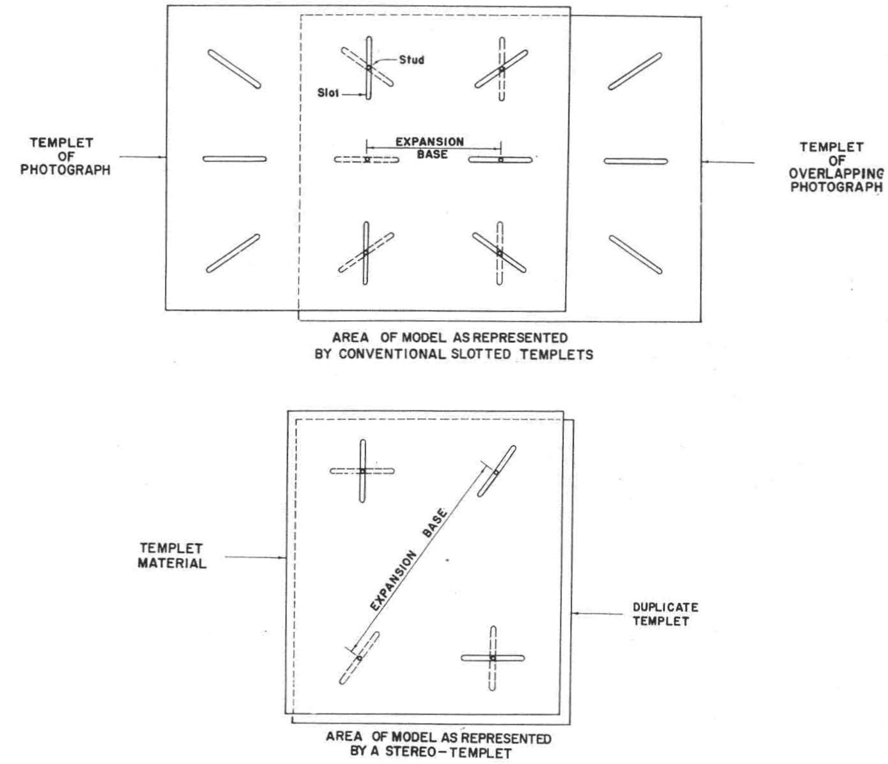

FIG. 9. Comparison of conventional templets to stereotemplets.

muth control line. Stereotemplets are particularly well-adapted for use as a scaling device for stereoscopic plotters of the "non-bridging" type. They are also of special value in areas where the amount and distribution of existing horizontal control is not suitable for effective stereo-triangulation by individual flight strips. Stereotemplets can be used with either vertical or oblique photography.

CONCLUSIONS

Photogrammetric research in the Topographic Division has paid off in better maps and lower costs. It is one of the major reasons why during fiscal year 1955, despite a manpower reduction of approximately 5 per cent, the output of the Division, measured in square miles of mapping, was increased by 25 per cent as compared to production in the previous year. Cost-wise, this research represents less than 1 per cent of the total budget for topographic mapping. Thus it is planned to continue the investigations into better photogrammetric instrumentation and methods with the hope of continued reductions in our over-all mapping costs.

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*Economic Factors in the Integrated Photogrammetric System of the U. S. Geological Survey**†

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THE United States Geological Survey is now in the process of affecting important changes in its mapmaking procedures. These integrated changes affect all the major aspects of the topographic mapping operation: aerial photography, photogrammetric instruments, plotting techniques, field operations, cartographic finishing, and reproduction processes. It is the purpose of this paper to review the economic background of this transformation and to discuss, in simple terms, advantages of the new system from the economic point of view.

To begin with, a brief outline of the principal changes in instrumentation needs to be stated, so that the transformation can be viewed in proper perspective. Prior to instituting the new system, the Geological Survey operated some 350 Multiplex plotting units, utilizing some 800 Multiplex projectors, including those used in bridging. In addition, 69 Kelsh plotter units and 9 heavy plotter units were in operation. Under the new system, the Multiplex projectors are being replaced by ER-55 projectors, to be used principally with twin low-oblique photography. Also, Twinplex plotters are being installed for aerotriangulation of twin low-oblique photography. Because of increased efficiency resulting from the new techniques and instrumentation, the planned replacement rate is 2 units of ER-55 equipment for 3 units of Multiplex equipment;

* This paper is a contribution to Commission IV of the International Society of Photogrammetry.

†Publication authorized by Director, U. S. Geological Survey.