*Evaluation Report on the Accuracy of Trimetrogon Compilation Techniques**

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ABSTRACT: *This paper gives a brief résumé of the history of trimetrogon mapping and its current use in the Air Force's mapping program. The necessity for a proper evaluation of the trimetrogon mapping technique is explained and the advantages of such an evaluation are considered. The author outlines the results of a comprehensive testing program designed to indicate the accuracy potential of various trimetrogon compilation techniques used over the past seventeen years and provides a basis for recommending the most efficient instruments and techniques to be used under varying conditions of control, photo-quality and terrain.*

THE Special Maps Branch, formerly the Trimetrogon Section, of the U. S. Geological Survey pioneered in the development of the trimetrogon method of mapping, and has been actively engaged in trimetrogon compilation methods for the past 17 years. The passing years have seen many refinements and improvements made to the original technique until now trimetrogon compilation is an accepted standard of mapping for small-scale reconnaissance purposes. However a need existed for an evaluation of current trimetrogon compilation methods. Such an evaluation was recently completed in the Special Maps Branch by testing the trimetrogon techniques under actual working conditions and is the subject of this report.

A major portion of the Special Maps Branch's activities in the small-scale trimetrogon-mapping field has been centered around the Air Force Joint Use—Approach Chart 1:250,000 Scale program. One of the requirements established by the Aeronautical Chart and Information Center of the Air Force for completed compilations under this program is to establish a category designation of accuracy for each chart. These categories are designated as *A*, *B*, *C*, *D* or Unreliable, and are based on 90 per cent of well-defined check-points being within certain prescribed distances of their true geographic position. Category-*A* requirements are that 90 per cent of all clearly-defined check-points will not exceed a limit of error of 500 feet; the limit of error for category *B* is 1,000 feet, and for category *C* is 2,000 feet. Category *D* and Unreliable will not be considered in this report.

In order to ascertain which category of accuracy could likely be met, it was necessary to develop certain standards which would help to determine the probable accuracy of a proposed trimetrogon project. Knowledge of this kind would also be valuable in determining the advisability of proceeding with a trimetrogon compilation when available source material of a certain known accuracy existed for the area. With these needs in mind a testing program was established.

The first problem to be considered was the selection of a test area containing varied conditions of relief and culture for which there existed category-*A* map coverage and first-quality trimetrogon photo coverage. An area of approximately, 1500 square miles in the immediate vicinity of Tucson, Arizona met these conditions. Map coverage consisted of U. S. Geological Survey 1:62,500 scale quadrangle maps, surveyed during the period from 1938 to 1943. The photo coverage consisted of excellent trimetrogon flights exposed in 1949 at a 25,000-foot altitude. The flights selected had a spacing of approxi-

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mately 30 miles and tie points were located within a maximum distance of two inches above the respective principal points of the oblique photographs.

AERO TRIANGULATION-ACCURACY TESTS

The first test concerned the radial-control or scale-solution technique. The intention here was to ascertain what conditions of given control would permit a trimetrogon-scale solution to satisfy category-*A* requirements, and by an appropriate reduction of given control points also to determine the minimum number of control points necessary to maintain that accuracy. The scale solution was accomplished by routine radial-templet techniques at 1:62,500 scale, using the U. S. Geological Survey maps for geographic position. A total of 31 well-defined points, symbolized as control, were selected from the maps and identified on the photographs. Three independent scale solutions were then completed with the following results:

In the first solution, in which all 31 control points were visible, 18 points intersected at their true positions and eleven points were located within a maximum error of 470 feet from their true position. The remaining two points were located within a maximum error of 574 feet from their true position. Figure 1 illustrates the location of all 31 control points relative to the flight lines and identifies the 18 control points which held their true position. These results satisfied the requirements of category-*A* accuracy.

Using the same templets, a second scale solution was then completed, covering 5 of the 18 previously held control points leaving only 13 stations (see Figure 2) to control the assembly. After this scale solution had been completed, these 5 control points were uncovered and rated along with the remaining 26 control points for positional error with the following results: Fifteen control points intersected at their true position, 14 points were located with a maximum error of 469 feet from their true positions and the remaining two points were located with a maximum error of 625 feet from their true positions. These results also satisfied the requirements of

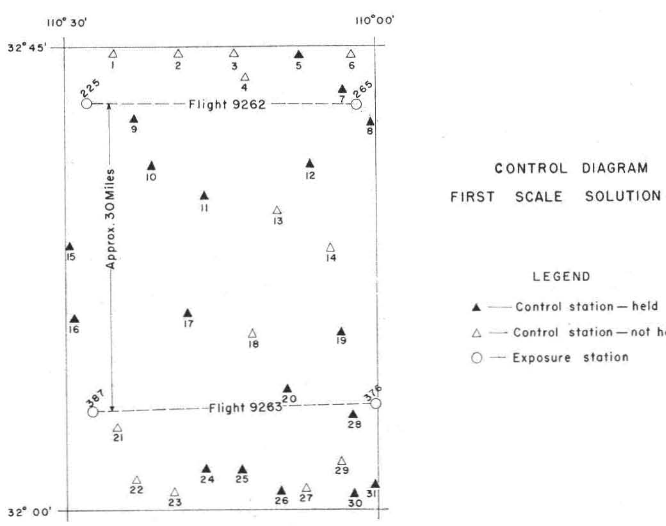


FIG. 1

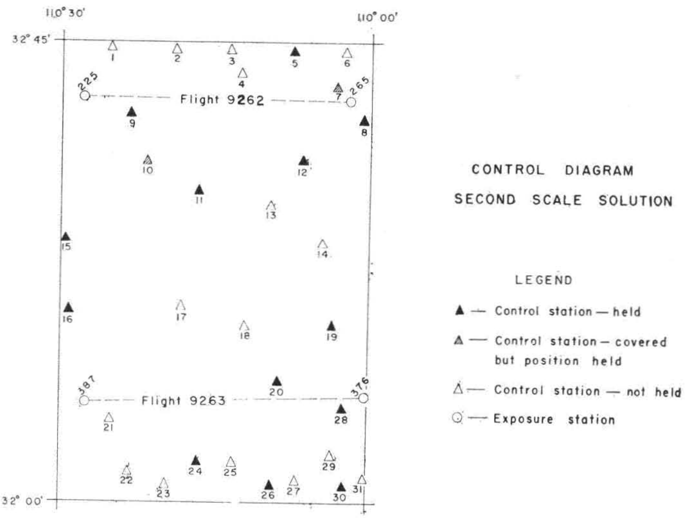


FIG. 2

category-*A* accuracy.

A third solution using the same templets was then completed in which 13 out of the original 18 primary-control points were covered and later rated in similar fashion to the first relay. Thus a total of only 5 stations (see Figure 3) were used to control the assembly. Ten points intersected at their true position, 18 points were located within a maximum error of 469 feet from their true position and the remaining three points were located within a maximum error of 886 feet from their true position. These results also satisfied the requirements of category-*A* accuracy.

Additional scale solutions with a further reduction of control stations were not attempted because the third assembly approached the minimum requirements of category-*A* accuracy and the maximum error was approaching 1,000 feet.

These results indicate that trimetrogon scale-solution techniques can satisfy category-*A* requirements. However, it should be recognized that the conditions of control and photo quality available for this test purpose were almost perfect, and should not be confused with the average conditions of control and photo quality found on routine assignments. Neverthe-

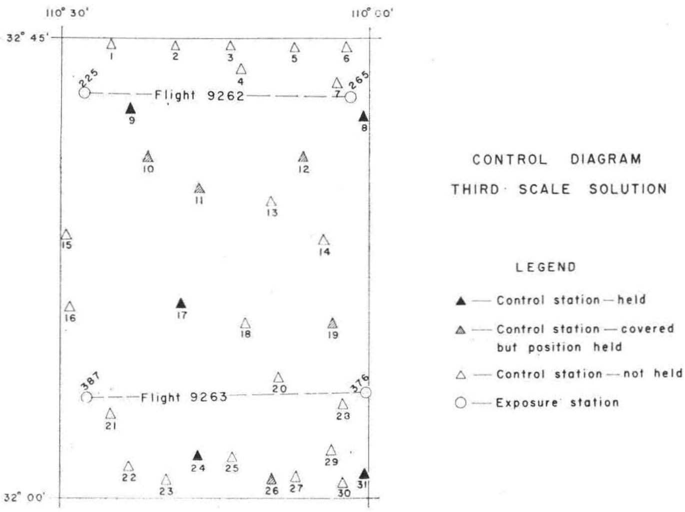


FIG. 3

less the test results provide us with a basis for outlining the conditions necessary to produce a category-*A* scale solution. We know now that the photo quality must be good enough to permit 90 per cent positive identification of control points and the flight spacing should not exceed a width-height ratio of 5 to 1. Also, and of equal importance, the given control must consist of 15–20 well-defined stations, advantageously spaced throughout a 1:250,000 scale chart area. Unless these conditions are satisfied it would be extremely difficult to justify any claim of category-*A* scale-solution accuracy; actually the probable accuracy of the average assignment would be closer to category *C* and under good conditions, might reach category *B*.

Test of Vertical and Oblique Sketchmasters[1]

Having a scale solution, and consequently a point base of known accuracy, it was possible to make a comprehensive test of the vertical and oblique sketchmaster instruments as well as the stereoblique plotter under actual operating conditions. The sketchmasters have always been the work horse of trimetrogon planimetric-compilation operations, but here again more factual evidence was needed to attest to their accuracy capabilities or limitations. To establish this information it was decided to test the instruments under varying conditions of relief, at varying horizontal distances from the nadir point, and by varying the density of detail points used to control the transferred detail. The completed compilation in each case was checked for accuracy and alignment of features by comparison with the U. S. Geological Survey maps.

Photographic detail was delineated at normal density and transferred to the point base under two separate conditions of detail-point selection. The first transfer operation was completed with an average of 4 to 5 detail points on each oblique photograph, while the second transfer was completed with an average of 13 to 14 points per photograph. The accuracy and alignment of the transferred detail were then evaluated and rated by categories of terrain conditions and horizontal distances from the nadir point. Terrain conditions were considered in three groups; namely rugged, medium and flat. Horizontal distances from the nadir point were also considered in three groups; 1—the vertical photograph area, 2—the foreground area of the oblique photograph below the principal point, and 3—the area on the oblique photograph beyond the principal point. Although the final results do not indicate any unusual findings, they are rather interesting in some respects.

Vertical-photo compilation in the areas of medium and flat terrain remained well within the limits of category-*A* accuracy. However in the area of rugged terrain the resulting map fell off to category *B* with a maximum error of 1,400 feet. At least 90 per cent of the extreme errors found on the vertical-photo compilation occurred on ridge-line positions indicating the inability of the instrument to provide an accurate means of compensating relief displacement.

The accuracy of oblique-photo compilation fell off rapidly by comparison with the vertical-photo compilation. At horizontal distances out to, but not beyond, the principal-point location, and with an average of 4 to 5 detail points per photo, the compilation resulted in category-*C* accuracy in rugged terrain, category *B* in medium terrain, and category *A* in flat terrain.

At the same horizontal distances, but with an increase in detail points to an average of 14 for each photograph, the resulting compilation did not improve in accuracy sufficiently to raise the category rating for either of the three terrain conditions although a slight improvement was noted in the average error. An average of 6 to 8 points for each oblique photograph is considered normal for the usual production assignments considering the average quality of the photography and the amount of time usually permitted for this particular phase of operations. In other words, an average of 14 points per photograph would represent a maximum density of detail points.

The effect of relief displacement was even more noticeable on the accuracy of transferred detail from the oblique photograph. A maximum error of 2,500 feet in an area of rugged terrain occurred when a sharply rising portion of stream detail was transferred beyond the last detail point.

[1] These instruments have been described in detail by Buckmaster, J. L., "The Camera Lucida Aero-Mapping," Photogrammetric Engineering, Vol. XII, No. 2, June, 1946.

It was noted that in almost every instance when stream detail in areas of moderate and particularly rugged relief was transferred beyond the last detail point, it would be displaced radially and in towards the operator, indicating a strong tendency on the part of the operator to "rack" his instrument too fast when descending the slope.

Oblique-photo transfer work at horizontal distances beyond the principal point location proved to be no better than category *C* with the maximum density of detail points. However this accuracy was maintained only in the rugged terrain areas where the ridge lines were sharply defined. The extremely small-scale characteristics that are inherent far out on a trimetrogon-oblique photograph are not conducive to accurate compilation. Planimetric detail becomes extremely condensed and even large changes in configuration often are impossible to detect or become obliterated by the inking procedure used during the delineation operation. Also, as the vertical angles to points of detail become smaller with increased horizontal distances, the art of "racking" the sketchmaster to compensate differences of relief becomes even more critical. It was interesting to note that a substantially larger maximum error of ridge-line position occurred in areas of medium terrain. A maximum error of 3,000 feet occurred in this area against a maximum error of 2,500 feet in the rugged-terrain area. The broad, rounded ridge tops, characteristic of this type of terrain, are difficult to define and locate on an oblique picture.

These findings led to the establishment of a set of conditions or criteria to govern trimetrogon compilation techniques which can be used to determine the probable accuracy of a proposed trimetrogon assignment, as follows:

1. Picture quality must be such that it will permit delineation of detail with fidelity, as well as the selection of a sufficient number of detail points to control adequately either of the three different types of terrain conditions—that is, 4 to 5 points for each photograph in areas of medium or flat terrain, and a minimum of 15 points in areas of rugged relief.

2. Photo delineation and transfer operations must be restricted to the vertical exposures, and inside a boundary limited by the location of the principal points on the oblique photographs.

3. The tilt and focal-length characteristics of the photography must not exceed certain recognized mechanical limitations of the sketchmaster instruments, i.e. the tilt or depression angle of the photography should not vary more than plus or minus 2 degrees from the desired 30 degrees, and there should not be more than plus or minus 0.10 inch variation from the desired 6-inch focal length.

When these conditions have been satisfied it can be expected that trimetrogon compilation procedures will maintain the accuracy of a category-*C* scale solution in areas of rugged relief, a category-*B* scale solution in areas of medium relief and a category-*A* scale solution in areas of flat terrain.

STEREOBLIQUE PLOTTER AS A COMPILATION INSTRUMENT[2]

The final part of this report concerns the stereoblique plotter and its evaluation as a trimetrogon planimetric compilation instrument. Essentially, the stereoblique plotter (See Figure 4) is two photoangulators, coupled together in such a manner as to permit an operator to view a pair of oblique pictures stereoscopically, and trace onto a base the position of any photo detail as defined by the intersection of the two index lines on the photo arms. In a theoretical sense, the operation of the plotter provides an infinite number of detail points to position the photographic detail, and should permit greater accuracy than would be possible using a finite number of detail points, as is the case with the oblique sketchmaster. Inasmuch as identical areas, terrain characteristics, and base-control conditions were used for both the oblique-sketchmaster and stereoblique-plotter test, it was possible to make a true comparison of the two methods of oblique photo-compilation.

Regardless of the nature of the terrain and at photo distances not exceeding $2\frac{1}{2}$ inches above the principal points, the stereoblique-plotter compilation remained well within the accuracy of category-*B* re-

[2] This instrument has been described in detail by Lewis, J. G. "Mechanical Instrument For Plotting From Oblique Photographs," PHOTOGRAMMETRIC ENGINEERING, Vol. XI, No. 4, Dec. 1945.

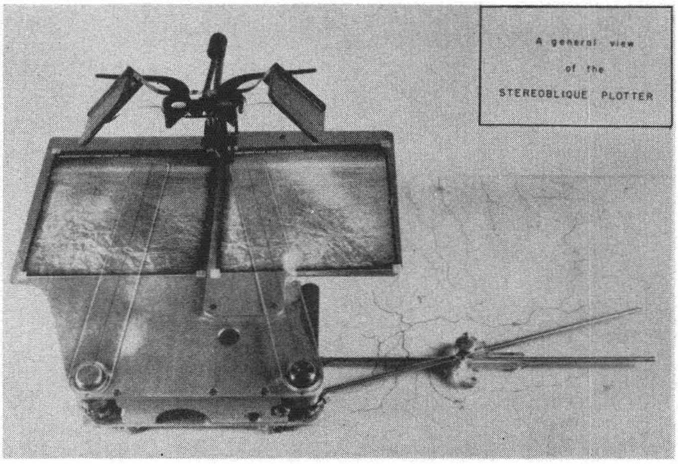


FIG. 4

quirements. Ridge-line and drainage configurations were improved, even over that of the sketchmaster compilation using the maximum number of control points. Figure 5 illustrates identical detail transferred by both the oblique sketchmaster and the stereoblique plotter.

Detail transferred from as far out on the oblique photo as $2\frac{1}{2}$ inches beyond the principal-point location retained the same general improvement or configuration as mentioned before. A review of these results showed that the stereoblique-plotter compilation was an improvement over the very best oblique-sketchmaster compilation. This was particularly noticeable in the areas of rugged relief where the stereoblique-plotter compilation resulted in category-*B* accuracy. Also the accuracy was retained at extreme photo distances. The compilation obtained from the foreground area of the oblique photography retained category-*A* accuracy in both medium and flat terrain.

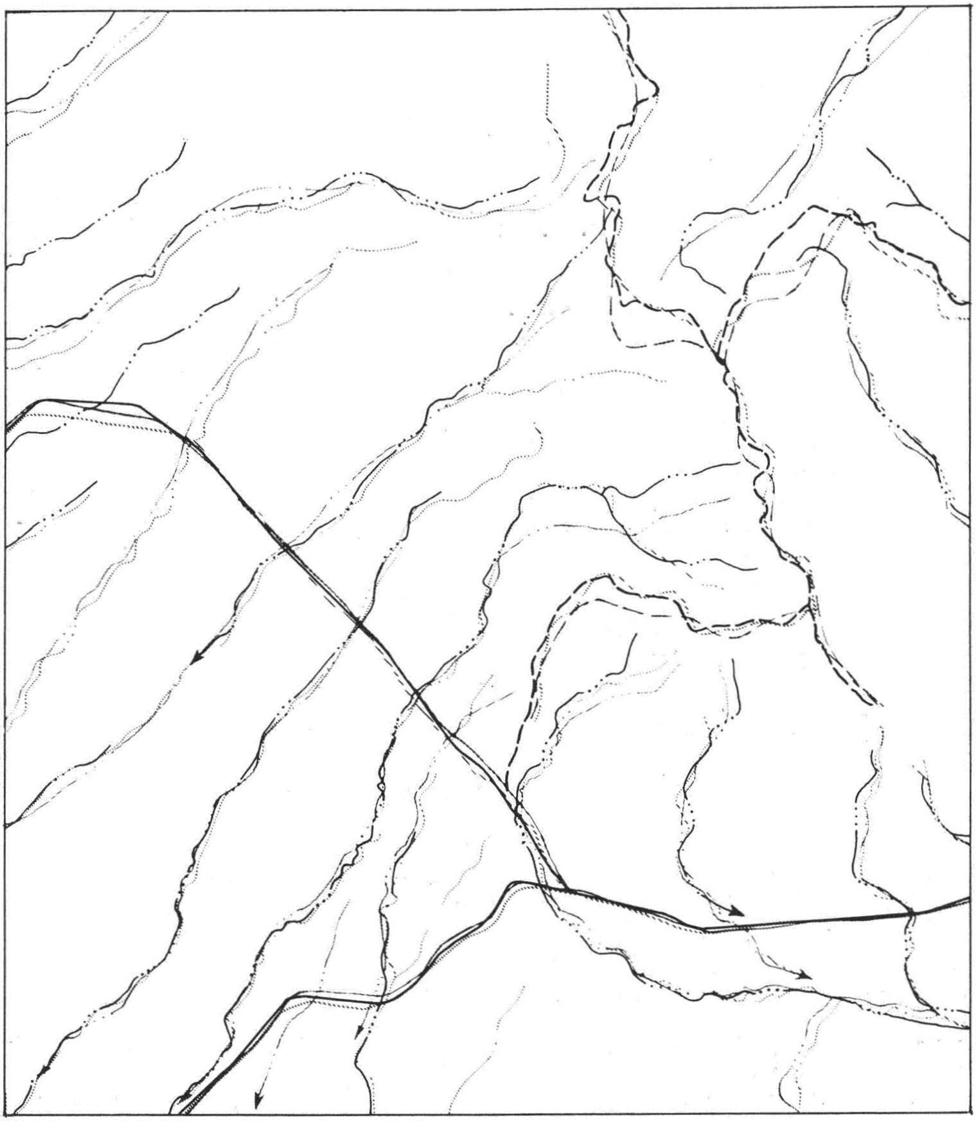
The test results showed that the stereoblique plotter is an instrument capable of producing a compilation from oblique photos with much more accuracy than is possible to obtain by oblique-sketchmaster techniques. It can also be recognized as an instrument capable of making adequate use of approximately 25 per cent more area of the oblique photograph than the sketchmaster instrument.

From a production view point, the stereoblique-plotter technique eliminates stereoscopic delineation and inking of photo detail, the selection of all detail points, and the use of the oblique sketchmaster. However, effective stereoblique-plotter compilation requires a radial-control solution indicating the nadir position of each vertical exposure. To achieve such a solution requires a slight additional expenditure of man hours over the normal time required to produce a radial-control solution for oblique-sketchmaster compilation. The additional cost can easily be justified in view of the certainty of producing a more-accurate compilation, which as a matter of fact, would expedite the hypsographic and editing phases. The demands of photographic quality and given control are no different than those expressed as necessary for successful oblique-sketchmaster compilation.

A comparison of the oblique-sketchmaster and stereoblique-plotter compilations on a man-hour or time-cost basis showed that the oblique-sketchmaster operations—such as photo delineation, selection and intersection of a maximum number of detail points—and the actual transfer of detail required exactly the same number of man hours as the stereoblique-plotter operations.

In view of these results it appears that the stereoblique plotter is a more efficient instrument than the oblique sketchmaster for trimetrogon oblique-picture compilation and should be considered the basic instrument for that type of compilation. The vertical sketchmaster is capable of providing the same characteristics of compilation accuracy as the stereoblique plotter, and should be used to augment that instrument for areas of vertical-photo compilation.

A more detailed account of the entire



LEGEND

—— Map detail ········ Stereoblique plotter detail

—— Oblique sketchmaster detail

FIG. 5

evaluation program has been written and copies are available on request to the Geological Survey. For those persons interested in trimetrogon-charting techniques, the complete report contains additional interesting facts and figures.