*A Test of 70 mm. Format, 1½-Inch Focal Length Photography for Topographic Map Compilation**

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ABSTRACT: *The concept of using small format aerial photography for stereocompilation is discussed. The results of tests using 70 mm. format 1½-inch focal-length photography exposed at flight altitudes of 40,000 feet for stereocompilation and stereo-aerotriangulation are presented. It is concluded from these tests that with sufficient ground control the uncompensated 1½-inch focal-length 70 mm. format test photography is adequate for compiling planimetric detail for 1:50,000 publication scale. The magnitude of residual errors in supplementary control established by stereotriangulation with the test photography precludes use of the control for compilation of 1:50,000 scale maps according to National Map Accuracy Standards. With provision for lens distortion compensation and adequate ground control, the high altitude photography can be used for topographic compilations with a contour interval of 40 meters or greater.*

INTRODUCTION

WITH development of complex high-altitude aircraft, the space available for cartographic camera installations is gradually diminishing. In recognition of this, the U. S. Navy is attempting to develop compact reconnaissance-type cameras that also have the potential for procuring photography suitable for map compilation or revision, target location, and extension of geographic control. One approach to this problem has been the development of 70 mm. format 1½-inch focal-length, wide-angle cameras. The Naval Photographic Interpretation Center has determined that this type of camera can obtain high-altitude (40,000 feet) photography adequate for photo-intelligence. However, the 70 mm. reconnaissance cameras contain lens distortion which should be compensated if the photography is to be used for mapping. In order to determine the degree to which this photography could be used for mapping, the Naval Oceanographic Office, at the direction of the Naval Bureau of Weapons, established a project in 1957 to perform a series of operational mapping tests using photography taken with a 1½-inch focal-length LA-26 (CAX-12) camera, a 1½-inch X70-2 camera and a 6-inch focal-length 9×9-inch format CA-14 (T-11) camera. A complete report on this study was published in April 1962.[1]

During the period of May 1957 to December 1958, a series of mapping tests were conducted in which the results obtained with photographs taken with the LA-26 camera, equipped with a 1½-inch focal-length Cartogon lens, were compared with results from photographs taken with the CA-14 6-inch focal-length cartographic camera. These tests consisted of the compilation of a topographic map from a stereo model comprised of two exposures taken over the Phoenix Test Area and the stereotriangulation of 18 exposures in the same general area.

The quality of the 1957 photography was not entirely satisfactory for determining its potential for mapping. For this reason, additional 70 mm. format, high-altitude photography was obtained in the same area in October 1959, to take advantage of recent improvements in camera design. Supplemental photography was obtained simultaneously with two LA-27 cameras mounted to provide split-vertical coverage. A CA-14 camera was installed to provide 9×9-inch format coverage for comparison.

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Preliminary Operations

Multiplex diapositives of the selected vertical exposures were prepared with an X-PAX-1 multiplex reduction printer (Figure 1). This printer was developed by the Naval Photographic Interpretation Center for the Bureau of Naval Weapons. The printer may be set to any required reduction ratio between the limits of 35/28.182 and 41/28.182. The projection lens was designed as distortion free. Since the taking lens was intended to be distortion free no correction plates were prepared to compensate for lens distortion. However, the lenses of the taking camera were *not* distortion free and the effect of the uncompensated distortion remains in the system.

In addition to the diapositives, 4-time enlargements of the $1\frac{1}{2}$-inch focal-length basic verticals and 3-inch split verticals were printed with an Omega enlarger to assist in control identification and photo interpretation. Contact prints were made of the 6-inch photography.

Compilation and triangulation manuscripts were prepared at 1:36,000 scale to permit orientation of the stereo models at approximately the optimum projection distance for the multiplex plotters.

Stereocompilation Test

The stereocompilation test was performed with two stereoscopic models oriented in a standard multiplex plotting unit. The photography was obtained in a Fairchild LA-26 camera with GOERZ AEROGOR lens, calibrated focal-length 38.299 mm. The relative orientation was accomplished independently for each stereo model. As noted earlier, the lens distortion could not be compensated. After removal of y-parallax by conventional

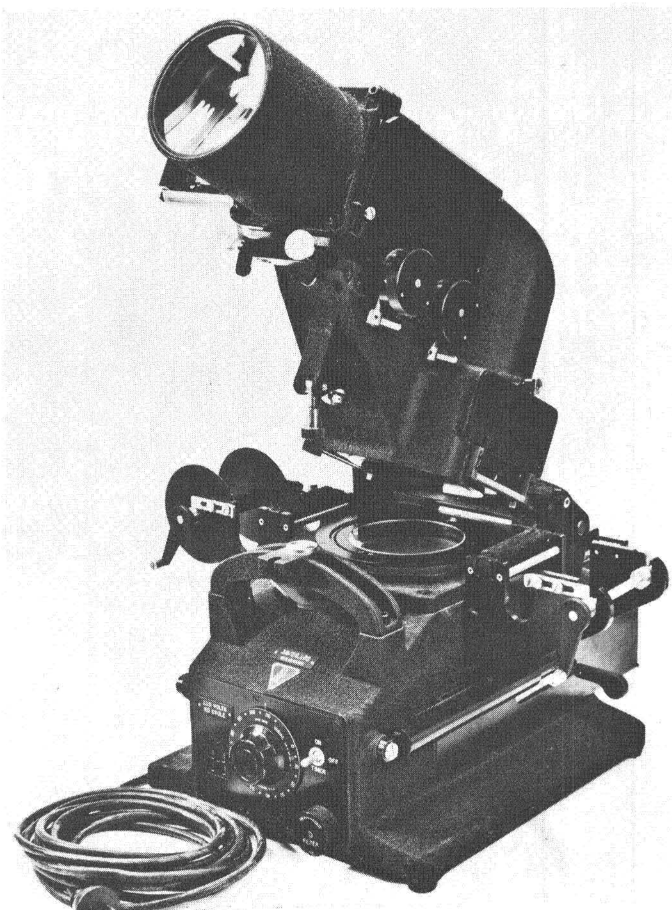

Fig. 1. X-PAX-1 multiplex reduction printer.

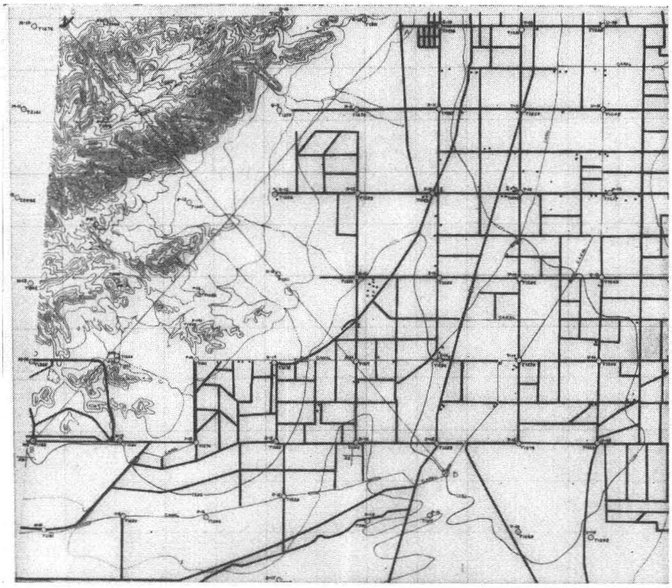

FIG. 2. Part of Phoenix area stereocompilation.

methods at the standard six positions in the stereo models, a y-direction split of the floating mark was seen in other areas of the models. The amount and direction of the split varied throughout the models.

The horizontal positions of 94 control points were established on the base manuscript and their elevations recorded. In addition, 26 bench marks were similarly located on the manuscript. These control points, a part of the Phoenix Test Area, were uniformly distributed throughout the stereo models and were identified from large scale photos in the Geodetic Data Folders of the Arizona Test Area.[2]

The test point elevations obtained from the stereo models contained systematic elevation errors resulting from uncompensated lens distortion, earth curvature, and atmospheric refraction. These errors were subsequently removed by the graphical method of Schut, described in the *Canadian Surveyor*, January 1958. The corrected elevation readings were tabulated and compared with the true values.

A topographic map was compiled according to the specifications for 1:50,000 scale, the selected hypothetical publication scale. Figure 2 shows a part of the area. It should be noted that the canal in the lower left crosses the 1200 foot contour three times.

Since no 1:50,000 scale maps compiled to the specifications used for this test are available, film positives of 1:25,000 maps covering the compilation area were made at 1:36,000 scale for comparison. Profiles were prepared for the lines A–B and C–D on the test manuscript and the film positives of the source maps. Also 15 well-formed road intersections were selected and the horizontal positions compared on the test compilation and film positive.

ACCURACY OF STEREOCOMPILATION

For 94 horizontal points with known elevations and 26 vertical control points, the mean error of the uncorrected vertical measurements was +10.5 meters, and the standard deviation from the mean was 12.0 meters. After correction for lens distortion and earth curvature, the mean error was +7.0 meters and the standard deviation 7.1 meters. The 94 horizontal test points had a mean absolute horizontal deviation of 38 meters and a median deviation of 18 meters. In addition, the horizontal coordinates of 14 bench marks were scaled from the 1:25,000 maps. When these were combined with the 94 horizontal points, the mean absolute deviation was 47 meters and the median deviation 18 meters.

From the physical distribution of the horizontal errors within the stereo model, it seemed probable that some of the larger errors were due to misidentification of the control on the photography. To see if this were true the control stations were divided into three categories: points that were positively identified, points whose identification was rated good, and those that were considered difficult

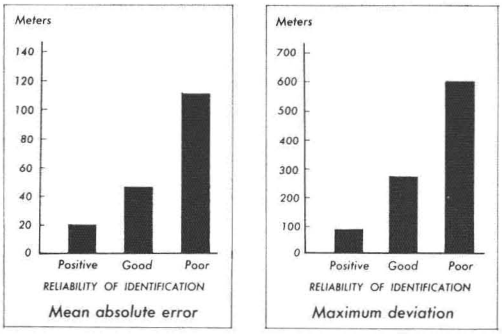

FIG. 3. Increase of horizontal deviation with decrease in reliability of point identification.

to identify or locate. Of the 120 test points, 60 were classified positive in identification, 38 good and 22 poor. Figure 3 illustrates the improvement in the mean absolute horizontal error and maximum horizontal deviation with increase in reliability of identification.

The plotted positions of 15 road intersections on the compilation conformed very closely to the positions on the film positive at the same scale. The true alignment of one intersection undergoing reconstruction at the time the photography was taken could not be determined from the $1\frac{1}{2}$-inch focal-length photography.

A comparison between profile lines A–B of the map and the compilation shows that for approximately 57% of their length they differ by over $\frac{1}{2}$ the specified contour interval (7.6 meters). After correction for lens distortion, 19% of the compilation profile differs from the map profile by over 7.6 meters and only 4% differs by the equivalent of a full contour (15.2 meters). For uncorrected profile C–D the variation is over 7.6 meters for 69% of the length and over a full contour for 29% of the length. After correction for lens distortion, 55% of the length differed by over $\frac{1}{2}$ contour and 2% by over a full contour or 15.2 meters.

STEREO-AEROTRIANGULATION

A 15 model stereotriangulation was performed with a multiplex "long bar" instrument. The photography was obtained in an X70-2 camera with Biogon lens of 38.299 mm. focal-length. The selected strip started at Los Angeles and progressed eastward toward Phoenix for approximately 75 statute miles.

Twenty-nine identifiable points were selected and marked on both the 4 × enlarged prints and the AMS 1:25,000 maps. Two points were selected opposite the principal-point of each photograph and so could be used in the bridging of successive models. The UTM grid coordinates and elevations for all points were obtained from the large-scale maps.

Residual parallax similar to that in the stereo-compilation was found in all models. The stereo-operator determined the best compromise parallax solution for the extension. All models were bridged on at least the center and one wing-point to within ±0.5 mm. at plotting scale.

HORIZONTAL ADJUSTMENT OF THE STEREOTRIANGULATION

The horizontal point positions established by multiplex were adjusted with the electronic computer program normally used by the Oceanographic Office. Adjustments were made based on six distributions of ground control points. Of these, two were selected to represent the six. The distributions were (a) the minimum case, consisting of one control-point in the initial, middle, and terminal model; and (b) 16-control-points consisting of 15 points in the two initial models and one in the terminal model. An adjustment based on 14 control-points in the initial model contained large residual errors averaging 1760 meters in northing and 297 meters in easting for the four control-points in the terminal model. The trend of horizontal residual errors in the stereo triangulation extension is shown in Figure 4.

VERTICAL ADJUSTMENT OF THE STEREOTRIANGULATION

For the purposes of this test, elevation errors were assumed to be independent of horizontal errors and were adjusted separately.

The multiplex extension elevation readings were graphically adjusted based on the level initial model, one control-point in the middle model and two points in the terminal model. The mean vertical error after adjustment was +0.2 meters and the standard deviation from the mean was 21.6 meters. The maximum deviations were −39.0 meters and +54.9 meters. Another graphic adjustment based on all control-points within the extension produced a mean error of +0.03 meters and a standard deviation of 5.2 meters. Maximum deviations were +14.9 meters and −18.0 meters with all other residual errors no greater than 5.2 meters.

PHOTO QUALITY

As stated before, 4× enlargements of the 3-inch photography and contact prints of the 6-inch photography were made for compari-

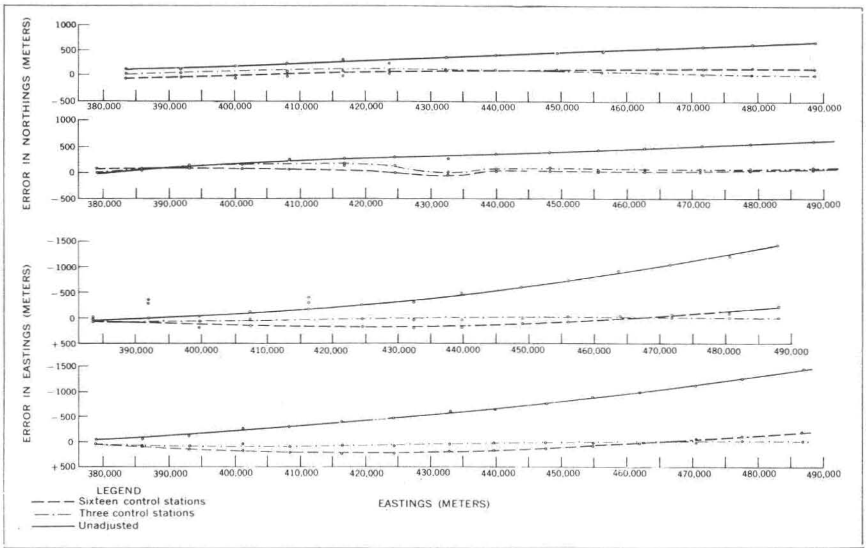

FIG. 4. Stereotriangulation horizontal residual errors.

son with the 1½-inch focal-length photos. However, only the 4× enlargements at approximately 1:80,000 scale of the 1½-inch photos were furnished the stereo operator for reference during the map compilation.

The definition of the enlarged 1½-inch prints appeared to be good, when viewed with 2× and 4× stereoscopes; however, the scale was too small for correct interpretation of all planimetric detail. In some areas, houses, trees, and tanks could not be differentiated. Roads, levees, canals, and railroads in other areas could not be accurately classified. Low trees and orchards symbolized on the AMS maps resembled cultivated fields on the photography. The 6-inch prints at the same scale as the 4× enlargements of the 70 mm. photos had much better definition.

The quality of the 6-inch focal-length photography was such that the rows in cultivated fields could be seen; the buildings showed up distinctly and the railroad could be identified from a clearly visible spur track. However, the roads and canals in some areas on the photos had the same appearance. The 6-inch photography was no better than the 1½-inch photography for classification of vegetation or identification of tanks. Split vertical 3-inch focal-length photography obtained for evaluation as a supplement to the 1½-inch coverage for photo interpretation of planimetric detail, was flown a day after the 1½-inch and 6-inch photography. The scale of this photography when enlarged 4× is larger than the 6-inch prints, but the definition of detail is slightly less, with greatest deterioration near the photo edges farthest from the isoline. The amount of detail that can be interpreted from this photography is approximately the same as from the 6-inch prints with the same difficulties in distinguishing between roads and canals and estimating the height of vegetation.

Microphotographs were taken from the 1½-, 3-, and 6-inch film of an airfield runway located within the stereocompilation. A Bausch and Lomb Model N eyepiece camera was attached to a Bausch and Lomb Model R microscope and exposures made on glass plates coated with Kodalith Ortho Type 3 emulsion. The microscope magnification was varied to produce prints from the 1½-, 3-, and 6-inch focal-length photography at the same equivalent focal-length. Figure 5 shows negative samples of each class of photo. The runway number "12" may be used to compare the image quality available in each sample.

CONCLUSION

Because the system tested is not distortion free, and because the number of samples used was limited, the results of the tests with the 1½-inch focal-length 70 mm. high-altitude mapping photography require qualified conclusions as follows:

1. Using 1½-inch focal-length, 70 mm. format photography without compensation for lens distortion it appears that:

a. Planimetric detail can be compiled for 1:50,000 publication scale within the limits of

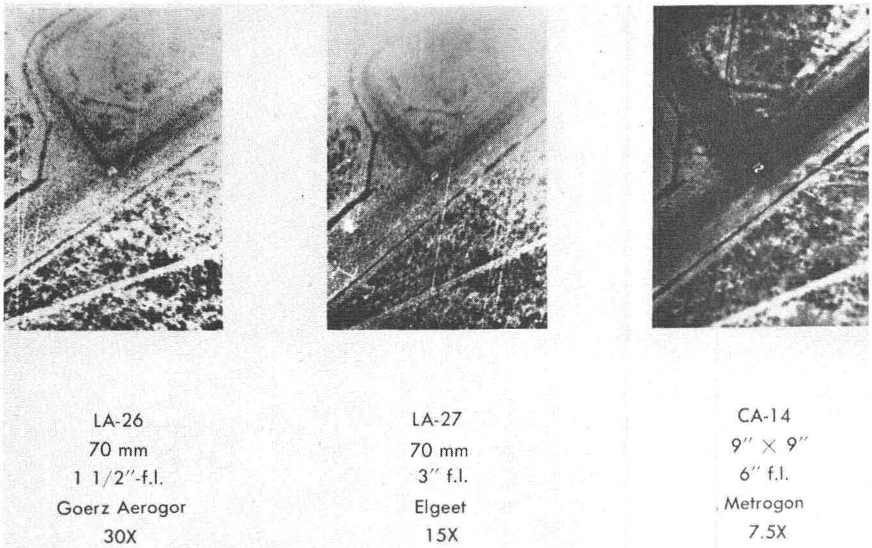

FIG. 5. Comparison of enlarged photos of an airfield located within the stereocompilation.

National Map Accuracy Standards.

b. Establishment of supplementary control by stereotriangulation and compilation of topography result in errors exceeding the limits of N.M.A.S.

2. With provision for lens distortion compensation and adequate ground control for each stereo model, 70 mm. format photography taken from 40,000 feet can be used for compilation of topographic maps with contour interval of 40 meters or more. It is highly possible that compensation for lens distortion in the 70 mm. system will permit using the same photography for establishing adequate supplementary control by stereotriangulation.

3. Improvement is required in photographic image quality of the 70 mm. format photography to minimize the occurrence of errors in photo interpretation and identification of geodetic control.

The Oceanographic Office is looking forward to development of a correction system which will produce virtually distortion-free stereo models.

REFERENCES

1. TR-120, Operational Test of 70 mm. Format High Altitude Photography for Mapping, U. S. Naval Oceanographic Office, April 1962.
2. Army Map Service, *Geodetic Data Folders 3, 4, and 5, Arizona Test Area.*

ABRAMS CHOSEN PRODUCT OF THE YEAR

The Abrams Aerial Survey Corporation of Lansing has been awarded the "product of the year" award for Ingham County by the Michigan Week Committee. Its product—*information.*

Announcement was made by Seward Cushman, business and product coordinator for a five county region. The award was made by Donald C. Weeks, Executive Director of the Greater Michigan Foundation, to Dr. Talbert Abrams, Chairman of the Board. In commenting on the award Dr. Abrams said "We are pleased to have a service rather than a physical product chosen for this award."