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Analytic Aerotriangulation Utilizing Skylab Earth Terrain Camera (S-190B) Photography

An RMS error of 15 metres in horizontal position was obtained for a 12-photo strip.

Abstract: *The feasibility of utilizing Skylab spacecraft Earth Terrain Camera (S-190B) 1:946,000 scale photography in analytic aerotriangulation procedures to provide low-order, high-density control suitable for small-scale mapping operations was investigated.*

The long-range application is the employment of this technique for coastal zone mapping at medium and small scales, surveys in remote areas, forest and range management, various planning activities, and route location for highways, pipelines, transmission lines, and canals.

The National Oceanic and Atmospheric Administration, National Ocean Survey (NOAA/NOS), office-identified the locations of 29 photo control points of known position and elevation on a strip of 12 photographs ranging along a 350-mile track from Charlotte, North Carolina, to the Rappahannock River in Virginia. The coordinates of pertinent images on each photograph were observed on comparators operated by NOS, and the resulting data were then processed through an established analytic aerotriangulation system of computer programs. A block adjustment was performed holding to 14 of the office-identified photo control points. The accuracy of the solution was evaluated by comparing the analytically computed ground positions of the 15 withheld photo control points with their known ground positions. A horizontal position RMS error of 15 metres was attained. The maximum observed error in position at a control point was 25 metres.

Introduction

A basic framework of geodetic control is essential for coordinating surveys and for the mapping of large areas. In the United States, the first and second-order horizontal and vertical control surveys conducted by the National Ocean Survey (NOS) of the National Oceanic and Atmospheric Administration (NOAA) provide this framework of geodetic control. Additional control surveys of third-order accuracy by federal and state agencies then subdivide or extend the basic network by triangulation, traverse, and leveling methods in order to bring the control into the areas to be mapped. The control stations established by these surveys are usually monumented for future use.

Photogrammetry can then be used to extend the basic monumented control network directly into the photographed area by using aerotriangulation methods to bridge between the high-order arcs of existing control. This procedure yields nonmonumented control and reduces the need for field-

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established photoidentifiable control for orienting stereoscopic models on plotting instruments for map and chart compilation.

Analytic aerotriangulation is a digital solution based on observed coordinates of the images created by pertinent objects on each photograph covering the area. The analytic solution possesses a higher accuracy potential than analogic stereotriangulation, which depends on measurements made on a sequential series of overlapping stereomodels. The advantages of analytic aerotriangulation accrue from automation, digital accuracy, least-squares adjustment, and freedom from the mechanical discrepancies contributed by the stereoscopic analog plotting instruments. In addition, the systematic errors such as camera-lens distortion, film shrinkage, atmospheric refraction, etc., can be more effectively eliminated by analytic methods than in analog stereotriangulation procedures.

ANALYTIC AEROTRIANGULATION MATHEMATICAL BASIS

The principle of collinearity provides the basis for the NOS method of analytic aerotriangulation.[1-3] Every object, its photographic image, and the camera station must lie on a common straight line, as defined by the method of least squares in which the sum of the squares of the residual errors of image coordinate measurement is minimized. This method is used because more observational information is available than is required for a unique solution. The computation requires initial approximations of the unknown parameters and is iterative. The least squares solution provides corrections to the approximate values of the parameters. If the initial approximations are coarse, the corrections are added to them, giving fresh and improved values for a new solution. Least squares is used again to provide another set of corrections, and the procedure is repeated until some criterion of convergence is satisfied.

OBJECTIVE OF THE NOAA/NOS INVESTIGATION

The immediate objective of the NOAA/NOS study was to investigate the feasibility of using Skylab Earth Terrain Camera (S-190B) photography in analytic aerotriangulation procedures to provide low-order, high density control suitable for small-scale mapping operations.

THE EARTH TERRAIN CAMERA (S-190B)

The S-190B Earth Terrain Camera (ETC) is located behind an optical glass window in the Scientific Airlock (SAL) on the antisolar side of the Orbital Workshop (OWS). The exposed film is returned after each Skylab mission for processing and analysis on the ground.

The ETC has a modified Hycon KA-74 reconnaissance camera body with a bidirectional focal plane shutter and vacuum film flattening.[4] It is equipped with an *f*/4 lens having a focal length of 460 mm (18 inches), color correction, and a maximum radial distortion of 10 μm. Forward image motion compensation is provided by rocking the entire camera in its mount during the exposure. The ETC has a limited field-of-view of 14 degrees across the flats, based on the photographic format size of 4.5 inches square, and provides ground coverage of 109 km square per frame at a scale of 1:946,000.

The ETC is not a metric camera in the photogrammetric sense because of the use of a focal-plane shutter, and because the image frame, including the fiducial marks, is a part of the removable film magazine. The shutter motion causes a slight scale change in the flight direction, and the principal point cannot be precisely located because the image frame and the fiducial marks are not in a fixed position relative to the camera lens. When the camera is operated at 60 percent overlap, the base-height ratio is only 0.10; thus, any stereoscopic height determinations from the photographs have especially limited accuracy.

THE PHOTOGRAPHY

Skylab photography was secured over the test site during orbit 36, on September 12, 1973, (SL-3), using Aerial-Color, High-Resolution SO-242 film. Second generation transparencies, positive in tone and direction when viewed on the emulsion side, were made from the original film by printing emulsion-to-emulsion in contact. These 1:946,000 scale 4.5 × 4.5-inch transparencies and 9 × 9-inch contact paper prints were provided to the Coastal Mapping Division, of the National Ocean Survey, for processing through its analytic aerotriangulation system.

The 60 percent overlap photography consisted of a strip of 12 photographs along a 350-mile track from Charlotte, North Carolina (frame 86-288), to the Rappahannock River in Virginia (frame 86-299). Although the photography provided sharp high resolution imagery, the selection of pertinent images for measurement on the comparator was hampered by an extensive cloud cover on most of the pictures.

PHOTO CONTROL

Sufficient photo control is required to orient the photography in order to implement analytic aerotriangulation methods. Photo control refers to the establishment of horizontal positions and/or elevations, with respect to the basic monumented geodetic control network, of selected objects that create sharp and easily identifiable point images on the pictures. The positions and/or elevations are usually established in the field by third- and fourth-order triangulation, traverse, and leveling methods. For the more precise photogrammetric surveys, special targets are placed on the photo control points prior to photography in order to facilitate accurate office-identification of these points.

The field establishment of photo control for the Skylab project was not feasible because of funding problems and other NOS mapping commitments. Consequently, office-identification of photo control points was undertaken. Despite the cloud cover, 29 photo control points were office-identified on the Skylab photography. Road intersections were located by stereoscopically examining the photographs and comparing them with 1:24,000 scale USGS quadrangles covering the area. In addition, aeronautical aids to navigation and airport runway ends were identified on the pictures and their positions and elevations determined from data secured by the Coastal Mapping Division under its Airport Obstruction Chart Survey program.

Table 1 describes the stations and their accuracy. Their location on the ETC photographs is shown in Figure 1. All of the stations were at least ¼ inch in from the sides of the 1:946,000 scale 4.5 × 4.5-inch transparencies. Twenty-five of the stations appeared on only two consecutive overlapping photographs, whereas four stations appeared on three consecutive pictures.

TABLE 1. ESTIMATED ACCURACY OF OFFICE-IDENTIFIED CONTROL USED IN BLOCK ADJUSTMENT.

Control Station Number	Approximate Horizontal Accuracy (Metres)	Approximate Vertical Accuracy (Metres)	Description
288100 288101 293100 294102 295100 299100	15	5.0	Aeronautical Aids Horizontal and vertical positions from Airport Surveys, NOS.
288110 288111 290110 296111	5	3.0	Road Intersections Horizontal and vertical positions from 1:24,000 scale USGS quadrangles.
288201 288202 290201 290111 292110 292111 293110 296201 296110 298110 299110 299111	5	0.5	Road Intersection Spot Elevations Horizontal and vertical positions from 1:24,000 scale USGS quadrangles.
288120 291120 291121 293120 293121 297120 297121	1	0.3	Centerline Runway Ends Horizontal and vertical positions from Airport Surveys, NOS.

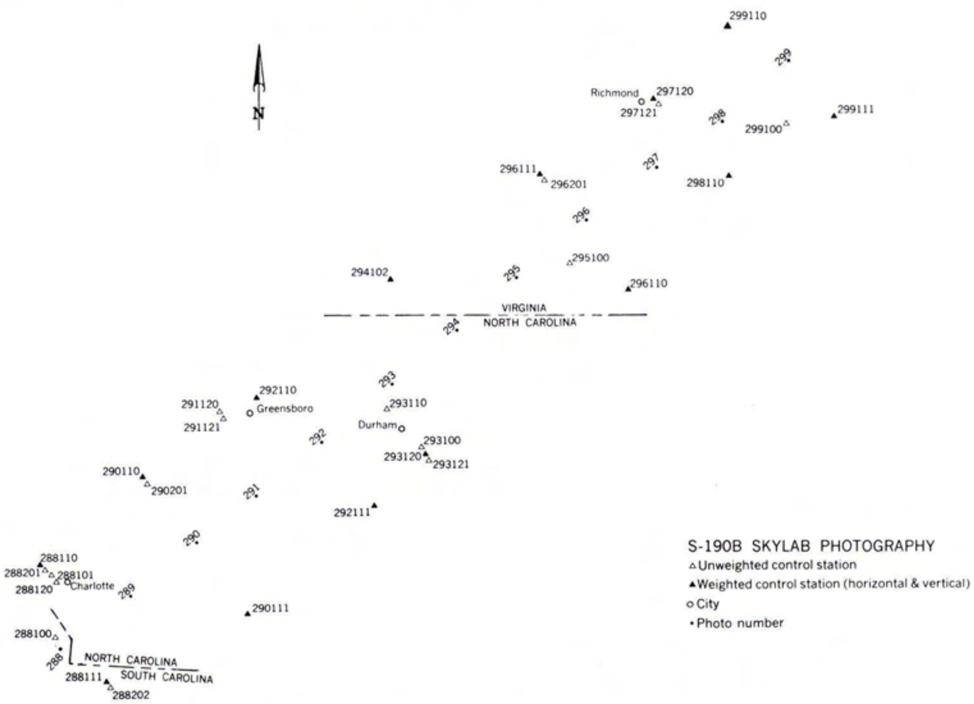

FIG. 1. Location of control on S-190B Skylab photography.

PASS POINTS

Pass points were drilled into the transparency emulsion only down the center of each photograph. The NOS programs allow two pass points to be placed in each of the nine conventional relative orientation locations, even though one pass point can provide all of the data needed for the analytic computations. If one of the pass points in a location exhibits a large residual discrepancy during the computations, it is discarded and its companion pass point substituted in its place.

MARKING AND PHOTOCOORDINATE MEASUREMENT

A Wild PUG-2 stereoscopic point transfer device, equipped with a 60-micrometre diameter diamond-tipped drill, was used to make the pass point holes in the emulsion. The photo control station images were not drilled in order to preserve the sharpness of the imagery.

Measurement of the x and y photocoordinates for the pass points and control stations was performed on a Wild STK stereocomparator. The stereocomparator enabled the operator to stereoscopically transfer the images of the drilled pass point holes to overlapping photographs for measurement without actually drilling the images on the overlapping photos. The comparator measuring mark consisted of a 165-micrometre diameter black circle having a 20-micrometre black dot at its center. The dot was centered in the 60-micrometre diameter drilled pass point image when observing the photocoordinates for the point.

FIDUCIAL MARKS

The compensation for film distortion can be achieved by mathematically treating the photograph so as to place the fiducial marks back into their true positions.[5] The ETC has a series of drilled holes around the perimeter of the image frame, which created photographic images about 330 micrometres in diameter. For this reason, the comparator operator centered the 165-micrometre circle of the measuring mark on the four holes selected to serve as fiducial marks. As noted previously, the image frame and the fiducial marks are part of the removable film magazine and hence are not in a fixed position relative to the camera lens. Fortunately, the lack of precision in locating the principal point at the intersection of the diagonals joining the four fiducial holes is of minor consequence in narrow angle cameras, such as the ETC.[6]

Since the true positions of the ETC fiducial holes were not available, a nominal set of true fiducial coordinates was obtained by mounting each transparency, in turn, on the comparator and reading the photocoordinates for the four selected fiducial holes. The data were entered into a reduction program to accomplish the following tasks: (1) Correct the observed photocoordinates of the fiducial holes for comparator systematic errors; (2) determine by least squares methods a meaned set of nominal photocoordinates for the fiducial holes in a coordinate system having its origin at the principal point (intersection of diagonals joining fiducials 1-3 and 2-4) and oriented so that the direction of flight becomes the *x*-axis of the photocoordinate system. See Figure 2. The data were then processed through the NOAA/NOS analytic aerotriangulation system of computer programs.

COMPUTER PROCESSING

The NOS system for this study consists of five programs: (1) Image coordinate refinement and three-photo orientation; (2) secant plane coordinate transformation; (3) strip adjustment to ground control; (4) block adjustment; and (5) accuracy analysis.[7–14]

IMAGE COORDINATE REFINEMENT AND THREE-PHOTO ORIENTATION

The photocoordinates for the images on each SKYLAB transparency were processed through image coordinate refinement to correct them for the systematic distortions introduced by the comparator and film shrinkage. This operation also expresses the photocoordinates in a two-dimensional coordinate system having its origin at the principal point and oriented so that the *x*-axis is the direction of flight.

A published technical memo[15] indicates the camera lens distortion to be probably insignificantly different from zero. In addition, distortion due to atmospheric refraction at camera altitudes above 40 miles is relatively negligible. For these reasons, no attempt was made to compensate for these distortions during the image coordinate refinement. In addition, no coordinate refinements were applied to compensate for the distortions introduced by the focal-plane shutter and the errors in the forward motion compensation system.

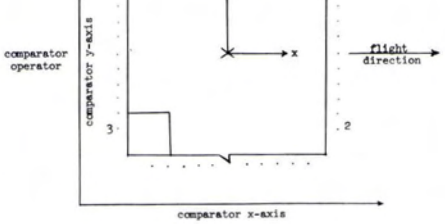

FIG. 2. Skylab transparency, emulsion side up.

The refined image coordinates, which are assumed to be free of systematic error and contain only residual observational discrepancies, were punched out to serve as input to the block adjustment program.

The program then proceeded to the three-photo camera orientation phase, which comprises an interrelated geometric fitting of the photographs based only on the refined photocoordinates of the pass points and is entirely independent from ground control data.

The iterative computation derives the orientation of each photo relative to the previous two in the strip and determines the positions of all objects in a common three-dimensional coordinate system. The collineation principle is imposed in a least squares solution that minimizes the residual observational discrepancies in the image coordinates. These errors are analyzed by the computer, which discards those images exhibiting large discrepancies, thereby providing "clean" photocoordinate data for all subsequent computations.

SECANT PLANE COORDINATE TRANSFORMATION

The 12-photo Skylab strip extended over the states of South Carolina, North Carolina, and Virginia. The computations require the ground positional data to be in a common three-dimensional coordinate system. In order to attain this condition, and also to compensate for the presence of earth curvature in the data, the Geographic Positions and elevations of the 29 office-identified control stations were processed through the Secant Plane Coordinate Transformation program to obtain secant plane coordinates for each station.

The program computations begin with a conversion of the Geographic Positions and elevations to an orthogonal geocentric coordinate system having its origin at the center of the earth as defined by the Clarke 1866 Spheroid. The geocentric coordinates are then transformed into a secant plane coordinate system in which the secant plane intercepts the earth's surface near the edges of the project area, so that most of the terrain objects will possess a positive Z (elevation) coordinate. The origin of the secant plane system is placed near the center of the project area.

STRIP ADJUSTMENT TO GROUND CONTROL

The analysis of three photographs at a time facilitates the joining of the separate triplets into a continuous strip and develops a set of model coordinates analogous to those obtained from conventional stereotriangulation on stereoplotting instruments. The horizontal and vertical strip adjustment transforms the model coordinate data into the prevailing ground control secant plane coordinate system by fitting to the control stations through the application of polynomial equations and least squares. Any large discrepancies appearing in the adjustment are corrected in order to obtain blunder-free provisional ground position data prior to entering the block adjustment computation.

The strip adjustment of the Skylab photography was performed by holding to the 14 photo control stations identified on Figure 1 by a ▲. These same stations were used later to control the block adjustment solution. The strip adjustment was performed twice—going from frame 288 to frame 299, and then going from frame 299 to frame 288. In both adjustments, the resulting discrepancies increased from about 25 metres at the beginning of the strip to approximately 100 metres at the end of the strip. Results of this nature do not occur on conventional strip adjustments at NOS. Their appearance on the Skylab bridge is assumed to be attributable to the inability to compensate completely for the systematic errors introduced by the nonmetric Earth Terrain Camera and by the office-identification of the photo control.

BLOCK ADJUSTMENT

Computations are usually terminated after strip adjustment for the case of a single strip of photos because there is little evidence of a significant improvement in accuracy by continuing on through block adjustment. As a consequence of the strip adjustment discrepancies, however, the block adjustment program was applied to the Skylab strip in an effort to optimize the accuracy of the solution.

The block adjustment uses the refined photocoordinates, together with the provisional object ground coordinates furnished by the strip adjustment, to solve simultaneously for the absolute orientation of all the photographs and the final coordinates for each object. NOS has developed three programs for operation on the CDC 6600 computer that accommodate as many as 25, 185, and 600 photographs in a single simultaneous least squares solution. The 600-photo version was used for the Skylab study.

All input/output is on tape for this version. Auxiliary disk storage is necessary because the program requires nearly one million words of memory. The photographs must be entered into the solution in an exact order. This ordering technique allows the program to take advantage of the banded structure of the reduced normal equation matrix, thereby eliminating arithmetic operations on the zero elements. This provides a more efficient computation and a much shorter computer running time.

All of the pass points and control stations contribute equations to the normal equation matrix and thus influence the least squares orientation solution. The finalized camera parameters from the orientation solution and the refined photocoordinates of the pass points and control stations are used to compute the final ground coordinates for these objects by intersection.

Thirty-six pass points (one in each relative orientation location) and all of the 29 photo control stations contributed observation equations to the normal equation matrix for the 12 photo Skylab block. The provisional ground coordinates for these objects should be reasonably close to their true values in order to minimize the number of iterations of the block adjustment solution. For this reason, the initial ground (secant plane) coordinates of the pass points were selected from the first half of the strip adjustment going from frame 288 to frame 299, and from the first half of the adjustment going from frame 299 back to frame 288. The known true ground (secant plane) coordinates were used as the initial coordinates for the 29 photo control stations.

WEIGHTING THE BLOCK ADJUSTMENT SOLUTION

The weighting of the block adjustment was performed by applying weights to the data during the computations. These weights can be defined as follows:

IMAGE QUALITY WEIGHTS

Image quality is influenced by lens resolution and the type of object creating the image. The block adjustment is weighted to favor the better quality images by multiplying each observation equation by a number that expresses its relative reliability.

CONTROL STATION WEIGHTS

When the observation equations are written for the control station images, their *X*, *Y*, *Z* ground coordinates should be favored during the adjustment. This is accomplished by increasing the main diagonal elements of the normal equation matrix, which are the coefficients of the unknown *dX*, *dY*, and/or *dZ* correction terms. These terms are reduced in size when the normal equations are solved, thereby constraining the adjustment in favor of the initial *X*, *Y*, *Z* ground values. Control stations not subjected to this weighting perform as pass points and provide a means for evaluating the accuracy of the block adjustment solution.

Empirical weight values are presently used at NOS instead of weights based on the standard error of the observations. The present program also multiplies the pertinent normal equation main diagonal terms by the control station weights instead of adding on a number to increase their size.

The inherent errors in using nonmetric photography and office-identified control made it necessary to perform numerous block adjustment solutions involving different combinations of control and weights. In general, all of the solutions yielded a horizontal position geodetic RMS error of about 15 metres for the 15 withheld (unweighted) control points. The best results occurred when using the 14 weighted control stations shown in Figure 1.

RESULTS OF THE BLOCK ADJUSTMENT SOLUTION

The iterative adjustment computation is terminated when the corrections to all of the angular camera parameters are less than 0.00001 radians (two arc-seconds). The Skylab block required five iterations of the orientation solution to achieve this condition, whereas only one such pass is usually needed in NOS operations that employ metric photography and field-identified control. Table 2 is a summary of the residual errors remaining at the 29 control stations after the final block adjustment. The results presented here are from a block adjustment solution in which the standard error of the ground control was assumed to be 4.1 metres.

The residual errors at the control stations are uniformly distributed throughout the area, and there is no evidence that the least squares solution was unable to absorb uncompensated systematic error; i.e., no large isolated discrepancies exist in the solution. The horizontal position geodetic RMS error for the 29 control stations was 12.218 metres and is equivalent to 12.915 micrometres at the photography scale of 1:946,000. A photogrammetric RMS error of 12.996 micrometres was computed, using the residual v_x and v_y plate observational discrepancies at all the images created by the 36 pass points and 29 control stations. The photogrammetric RMS error and the geodetic RMS error are nearly the same and imply an equal distribution of the block adjustment errors between the photogrammetric observations and the ground control observations. It should be noted that the photogrammetric RMS error is usually about 8 micrometres on NOS photogrammetric mapping projects.

The horizontal position geodetic RMS error for the 15 withheld control stations was 15.068 metres. A maximum error of 24.794

TABLE 2. RESIDUAL ERRORS IN METRES REMAINING AT EACH OF THE COMPUTED POSITIONS FOR THE 29 OFFICE-IDENTIFIED PHOTO CONTROL STATIONS AFTER BLOCK ADJUSTMENT SOLUTION AS EXPRESSED IN THE SECANT PLANE COORDINATE SYSTEM

Photo Control Station	*X*	*Y*	*Z*
△ 288100	11.738	−12.483	−30.343
▲ 288110	10.025	20.329	−233.104
△ 288201	10.991	7.727	−196.716
▲ 288111	−7.517	−5.612	172.285
△ 288202	−10.718	−2.895	134.556
△ 288120	14.378	9.686	−205.982
△ 288101	14.961	19.031	−210.726
▲ 290110	−2.030	6.814	11.736
△ 290201	3.301	−2.078	40.588
▲ 290111	1.143	−6.379	−86.241
△ 291120	−0.207	6.891	−78.019
△ 291121	12.644	−6.815	−25.212
▲ 292110	−1.150	6.593	−38.472
▲ 292111	0.491	−3.279	−5.378
△ 293100	−4.988	12.935	25.196
▲ 293120	−2.891	−0.096	−3.173
△ 293121	8.579	7.711	−5.563
△ 293110	13.274	9.672	−13.012
▲ 294102	1.034	1.407	2.332
△ 295100	15.142	−12.953	−70.711
▲ 296111	1.938	0.900	−7.411
△ 296201	−1.008	6.180	3.373
▲ 296110	−4.219	−0.994	29.125
▲ 297120	3.231	7.052	−137.767
△ 297121	1.667	2.042	−135.449
▲ 298110	−6.028	−3.617	85.999
△ 299100	−16.286	−18.695	−138.440
▲ 299110	−3.290	3.970	6.269
▲ 299111	0.296	−1.523	−26.832

NOTE: ▲ = weighted photo control station; △ = unweighted photo control station.

metres occurred at withheld control station No. 299100. No serious attempt was made to hold to the elevations of the control stations because of their inherent limited accuracy.

INVERSE OF THE SECANT PLANE COORDINATE TRANSFORMATION

After completion of the block adjustment, the adjusted secant plane coordinates were transformed back into the original ground coordinate system (geographic positions and elevations based on sea level) by applying the secant plane transformation in its inverse mode.

ACCURACY ANALYSIS

In order to evaluate fully the accuracy potential of the analytic system, a final computer program was used to develop the inverse of the matrix of normal equations, the variances, and the standard errors in X, Y, and Z at all of the points throughout the project area.

The variance-covariance matrix $\boldsymbol{E}$ of the coordinates determined for a point in the block can be expressed as $\boldsymbol{E} = \boldsymbol{Q}m_o^2$ where $\boldsymbol{Q}$ is the weight coefficient matrix of the points as derived from the inverse, and m_o is the standard error of unit weight for the problem and is considered to be essentially equal to the photogrammetric RMS error determined in the block adjustment solution. Both $\boldsymbol{Q}$ and m_o are relatively independent and provide a means for the comparison of tests conducted under varying conditions.

Table 3. The Standard Errors in Metres in the Secant Plane Coordinate System for Each of the 15 Withheld (Unweighted) Control Stations

Photo Control Station	X Metres	Y Metres
288100	9.201	9.529
288201	9.961	15.053
288202	10.164	12.360
288120	9.003	13.679
288101	8.916	14.029
290201	7.271	10.185
291120	13.554	16.164
291121	13.158	15.701
293100	15.650	11.110
293121	15.736	11.260
293110	9.967	9.494
295100	9.377	10.147
296201	7.949	7.844
297121	10.949	8.993
299100	9.084	13.678

$\text{RMS}_X = 10.963$
$\text{RMS}_Y = 12.216$
$\text{RMS}_{YX} = 16.414$ metres

The weight coefficient matrix $\boldsymbol{Q}$ is affected by the geometry of the block, such as the number of photographs and the number and distribution of horizontal and vertical control. The standard error of unit weight m_o is a measure of the precision of the system and is affected by the camera, comparator, effectiveness of the corrections for systematic errors, overlap, premarking, operational techniques, etc. Its value is relatively constant for a given set of techniques and allows one to upgrade the system by improving the techniques.

Table 3 shows the horizontal standard errors in metres in the secant plane coordinate system for each of the 15 withheld (unweighted) photo control stations, as derived from the variance covariance matrix $\boldsymbol{E}$. Their magnitude substantiates the validity of the geodetic RMS error found in the previous block adjustment solution.

Discussion of Skylab Aerotriangulation Results

The results of the block adjustment were reasonably close to the values to be expected from the Skylab photography. Our experience indicates that the block adjustment of a strip of metric 1:946,000 scale photography, using field-identified photo control, would yield a geodetic RMS error of about 14 metres. Assuming a maximum error of 20 metres introduced by the ETC and a maximum error of 15 metres for the office-identified photo control, the overall expected geodetic RMS error for the block adjustment of the Skylab strip increases to nearly 16 metres. As noted earlier, the actual geodetic RMS error achieved in the test was 12.218 metres for all 29 office-identified photo control stations and 15.068 metres for the 15 withheld or unweighted photo control stations.

The National Standards of Map Accuracy require 90 percent of all map points to be correct to within 1/50 inch or 0.51 mm for maps published at scales of 1:20,000 or smaller. Statistically, the Skylab results indicate that 90 percent of all the 29 control stations were held to within 20 metres, and 90 percent of the 15 withheld or unweighted stations were held to within 24.7 metres. It is evident, therefore, that if the positions of all the planimetric details required to construct a map of the area were developed digitally by analytic block adjustment methods, 90 percent of these planimetric points would also be correct to within less than 25 metres.

Thus, the analytic aerotriangulation method can be used in this manner with the 1:946,000 scale Skylab strip photography to construct a 1:50,000 scale map that will meet the National Standards of Map Accuracy.

The usual practice in mapping operations is to compile the planimetric details from stereoscopic models oriented to horizontal control established principally by analytic aerotriangulation procedures. Experience has shown that 90 percent of the horizontal photo control should be known to within 0.15 mm, as measured on the manuscript. This is equivalent to 24.75 metres at a map scale of 1:165,000. Thus, stereocompilation techniques can be combined with analytic aerotriangulation methods to construct a map at 1:150,000 to 1:200,000 scale from the 1:946,000 scale Skylab strip photography.

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Articles for Next Month

N. Balasubramanian and *Robert D. Leighty,* Heterodyne Optical Correlation (HOC).
Dr. T. J. Blachut, The Stereo-Orthophoto Technique in Cadastral and General Mapping.
Dr. T. J. Blachut and *M. C. van Wijk,* Results of the International Orthophoto Experiment 1972-76.
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Clifford W. Greve, Ph.D., Accuracy Prediction for the Orthophoto Mapping Process.
Jerry C. Ritchie, Frank R. Schiebe, and *J. Roger McHenry,* Remote Sensing of Suspended Sediments in Surface Waters.
Horst Schöler, System Errors of Differential Rectifiers with Optical Projection.