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Three-Photo Aerotriangulation

M. KELLER and G. C. TEWINKEL

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Technical Bulletin Series

This series of Technical Bulletins was inaugurated to present primarily to the personnel of the Coast and Geodetic Survey and incidentally to others technical information related to the Bureau's scientific and technical activities. Since many of the bulletins deal with new practices and new techniques, the views expressed are those of the authors and do not necessarily represent final Bureau policy.

Technical Bulletin No. 29 describes a documented program for computing the aerotriangulation parameters of a strip of aerial photographs through an analysis of three photographs simultaneously, advancing one photograph at a time. Corrections are included for lens distortion, film distortion, atmospheric refraction, and earth curvature (if desired). Blunders in the input data are detected and eliminated, and the rejection level is controlled by the user. The data are analyzed without reference to ground control which is imposed during a subsequent program called strip adjustment, a description of which was published as Technical Bulletin No. 23. The source program, written in Fortran IV language, includes complete test input and output data for an actual sequence of 17 photographs.

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Three-Photo Aerotriangulation

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ANALYTIC aerotriangulation is a precise computational technique for deriving ground coordinates of objects from the measured coordinates of their images which show on a set of overlapping aerial photographs. The solution is based on a relatively sparse distribution of control stations whose coordinates are known from previous classical measurements on the ground.

In a previously reported technique,[1] 12 separate computer programs were utilized on an IBM-650 computer. That solution was based on the analysis of two photographs at a time, after which the output was joined into a continuous strip and then was adjusted to agree with ground control information. The same general procedure is applied in this paper to three photographs instead of two. The act of joining the separate triplets is incorporated into the general procedure and does not constitute a distinct operation. At present, only two computer programs are applied, the second one being a modified form[2] of the strip adjustment program which was reported earlier.

The first of the two programs, called the three-photo analysis, includes the coordinate refinement procedure[3] that corrects the observed image coordinates for all the systematic errors and distortions of which we are aware.

The older two-photo technique has been rewritten and documented[4 5] in the form of four programs for the IBM-1620, a computer having 40K core memory.

The sample input and output, shown in appendixes 1 and 3, are considerably more extensive than might be necessary for simply documenting the solution. The voluminous data are included nevertheless because they comprise a record of actual data which are made available for anyone who might wish to test this or any other procedure. The data pertain to a 17-photograph test flight, over portions of U.S. Route 11 in the Shenandoah Valley of Virginia, at 20,000 feet with an RC-8 film camera. The same material was cited in Technical Bulletins Nos. 21 and 23.[6 7] Because the photographs were taken with 80 percent overlap, only alternate photographs are used in this presentation.

INTRODUCTION

The analysis of at least three photographs[8] at a time is considered necessary if aerotriangulation computation is to function as a single uninterrupted program. The reason for this is that the two-photo solution contains an insufficient geometric basis for rigorously judging whether an intolerable error or blunder exists in an observation of the abscissa of an image; the error merely gives rise to a corresponding elevational quantity without a reliable clue as to whether an observation is erroneous. On the other hand, the three-photo analysis allows the detection and evaluation of this x-discrepancy so that the computer can be programed to reject the observation.

This "provisional" solution is divided intentionally into two separate computer problems: (1) orientation, and (2) strip adjustment. However, these operations can be combined, if so desired. The reason for the division stems from the advantages of distinguishing between the internal photogrammetric precision and the accuracy in fitting the solution to ground control data. The two criteria are of very different character.

The photogrammetric solution includes numerous redundant data points; for example, 72 observation equations are formed for determining 48 unknowns, from which the least squares and statistical concepts can be relied on to yield a logical solution. As a consequence, the programer can include in the output three pertinent reliability (or precision) factors for: (1) each object, (2) each model, and (3) the entire strip of photographs.

The ground control data, however, are quite different for economic reasons: Usually it is necessary to control a strip of photographs with as few points as possible; erroneous control data result commonly from human blunders in handling the data before they are entered into

[1] Analytic aerotriangulation by W. D. Harris, G. C. Tewinkel, and C. A. Whitten, *Coast and Geodetic Survey Technical Bulletin No. 21*, corrected July 1963.

[2] Aerotriangulation strip adjustment by M. Keller and G. C. Tewinkel, *Coast and Geodetic Survey Technical Bulletin No. 23*, August 1964.

[3] Aerotriangulation: Image coordinate refinement by M. Keller and G. C. Tewinkel, *Coast and Geodetic Survey Technical Bulletin No. 25*, March 1965.

[4] Aerotriangulation strip adjustment using Fortran and the IBM-1620 computer by C. T. Horsfall, Federal Survey Department, Lagos, Nigeria. (Published by the *U.S. Coast and Geodetic Survey*, March 1965.)

[5] Electronic computer programs for analytical aerial triangulation by C. T. Horsfall, Federal Survey Department, Lagos, Nigeria. (Published by the *U.S. Coast and Geodetic Survey*, June 1965.)

[6] Harris, Tewinkel, and Whitten, see footnote 1.

[7] Keller and Tewinkel, see footnote 2.

[8] Use of triplets for analytical aerotriangulation by Edward M. Mikhail, *Photogrammetric Engineering*, vol. 28, no. 4, p. 632, September 1962.

the computer, and the magnitude and distribution of blunders do not conform very well to statistical correction in a computer for any given strip. Human judgment is needed to help in the analysis of any discrepancies. To facilitate the application of human judgment, this phase of computing is separated from the photogrammetric phase.

The strip solution is relatively short, requiring only 1 to 5 percent of the computer time needed for the photogrammetric phase, and consequently, this part of the solution can be repeated at small cost as often as necessary without repeating the previous difficult phase. The strip solution is designed specially to assist one in detecting, correcting, or eliminating blunders in the control data. This separate approach is considered to be practical, based on a distressingly large incidence of such blunders experienced during operations. As a consequence, the "provisional" solution provides sound control data, free from blunders and in a convenient form for entry into a subsequent or final "block" type of adjustment, if such an adjustment is considered desirable.

The three-photo solution also serves the authors as an educational link in the chain of development from the former two-photo solution to the eventual n-photo problem, because the solution introduces many added concepts that are necessary for the larger analysis. Among the examples: (1) Several different classes of observation equations are encountered, each introducing a slightly different set of unknowns; (2) the normal equation matrix is compressed systematically so as to minimize the size of the memory storage required; (3) the input data cards are sorted into a strict sequence before entry into the computer, and a computer test for the proper sequence is included; (4) a system is presented to test for observational blunders, to delete an image from the computation, but also to stop the computation if too many deletions are encountered; and (5) a numerical criterion for deletion is provided by the photogrammetrist as part of the input data so that the solution can be applied to situations requiring different levels of precision.

MATHEMATICAL BASIS

The mathematical basis was published in earlier Technical Bulletins,[9 10] and the pertinent formulations that are used in the computer program are stated again in this division. The novelty of this treatise lies in the manner in which the data are manipulated, rather than any new mathematical principles. The fundamental condition of collinearity on which the solution is based is that each object, its corrected photographic image, and the perspective center (lens point) of the photograph must be on a common straight line in space so that the sum of the squares of the residual-image positional errors is a minimum.

[9]Harris, Tewinkel, and Whitten, see footnote 1.

[10]Keller and Tewinkel, see footnote 2.

The collinearity equations are:

$$\frac{x}{z} = \frac{(X - X_0)a_{11} + (Y - Y_0)a_{12} + (Z - Z_0)a_{13}}{(X - X_0)a_{31} + (Y - Y_0)a_{32} + (Z - Z_0)a_{33}}$$

$$\frac{y}{z} = \frac{(X - X_0)a_{21} + (Y - Y_0)a_{22} + (Z - Z_0)a_{23}}{(X - X_0)a_{31} + (Y - Y_0)a_{32} + (Z - Z_0)a_{33}}$$

but they may be expressed also as:

$$\begin{aligned}
&x[(X - X_0)\sin\varphi + (Y - Y_0)\ (-\sin\omega\cos\varphi) \\
&\quad + (Z - Z_0)\ \cos\omega\cos\varphi] \\
&\quad - z[(X - X_0)\ \cos\varphi\cos K \\
&\quad + (Y - Y_0)\ (\cos\omega\sin K + \sin\omega\sin\varphi\cos K) \\
&\quad + (Z - Z_0)\ (\sin\omega\sin K - \cos\omega\sin\varphi\cos K)] = 0 \\
&y[(X - X_0)\sin\varphi + (Y - Y_0)\ (-\sin\omega\cos\varphi) \\
&\quad + (Z - Z_0)\ \cos\omega\cos\varphi] \\
&\quad - z[(X - X_0)(-\cos\varphi\sin K) \\
&\quad + (Y - Y_0)(\cos\omega\cos K - \sin\omega\sin\varphi\sin K) \\
&\quad + (Z - Z_0)(\sin\omega\cos K + \cos\omega\sin\varphi\sin K)] = 0 \quad (1)
\end{aligned}$$

in which x, y are the observed (corrected for lens distortion, etc.) coordinates of an image on a photograph relative to the perspective center, z is the focal length of the camera, X, Y, Z are the ground coordinates of the corresponding object in any right-handed Cartesian system, X_0, Y_0, Z_0 are the coordinates of the camera station (perspective center or lens point) in the same ground coordinate system, and the a's are trigonometric-orientation factors defined in Equation 3 following.

Equation 1 defines a projective transformation for converting the space coordinates of a set of objects into another set of space coordinates of the corresponding photographic images.

It has been found convenient to express Equation 1 in equivalent matrix notation:

$$[a_{11}, a_{12}, a_{13}]\begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} - [a_{31}, a_{32}, a_{33}]\begin{bmatrix} X - X_0 \\ Y - Y_0 \\ Z - Z_0 \end{bmatrix} = 0$$

or, applying determinants:

$$\begin{vmatrix} x & z \\ \mathbf{A}_1\cdot\mathbf{B} & \mathbf{A}_3\cdot\mathbf{B} \end{vmatrix} = 0, \quad \begin{vmatrix} y & z \\ \mathbf{A}_2\cdot\mathbf{B} & \mathbf{A}_3\cdot\mathbf{B} \end{vmatrix} = 0. \quad (2)$$

The A-matrix comprises a three-dimensional rotation of the x-, y-, z-image coordinate system about the perspective center so that the new coordinate x^*-, y^*-, z^*-axes are parallel, respectively, to the ground system X, Y, Z. The word "ground" is applied frequently in a relative sense in which the system is an arbitrary provisional

system (model coordinates), utilized until sufficient data are available to establish a factual ground system. The relation between the systems, x, y, z and x^*, y^*, z^*, is expressed by:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} x^* \\ y^* \\ z^* \end{bmatrix}$$

or expressed inversely as:

$$\begin{bmatrix} x^* \\ y^* \\ z^* \end{bmatrix} = \begin{bmatrix} a_{11} & a_{21} & a_{31} \\ a_{12} & a_{22} & a_{32} \\ a_{13} & a_{23} & a_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

or explicitly as:

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix} = \begin{bmatrix} A_1 \\ A_2 \\ A_3 \end{bmatrix}$$

$$= \begin{bmatrix} \cos\varphi\cos K & \cos\omega\sin K + \sin\omega\sin\varphi\cos K & \sin\omega\sin K - \cos\omega\sin\varphi\cos K \\ -\cos\varphi\sin K & \cos\omega\cos K - \sin\omega\sin\varphi\sin K & \sin\omega\cos K + \cos\omega\sin\varphi\sin K \\ \sin\varphi & -\sin\omega\cos\varphi & \cos\omega\cos\varphi \end{bmatrix}$$

or in matrix notation as:

$$\mathbf{x} = \mathbf{A}\mathbf{x}^*$$
$$\mathbf{x}^* = \mathbf{A}^{-1}\mathbf{x} = \mathbf{A}^T\mathbf{x}. \qquad (3)$$

Here the angles ω, φ, K represent sequential rotations of the x^*-, y^*-, z^*-axes, respectively, as defined specifically in Technical Bulletin No. 21.[11]

Equation 1 is enforced by (1) regarding x and y as observations, z as a constant, and all of the other parameters initially as unknowns; (2) deriving logical approximate values for the unknowns; and (3) computing and recomputing corrections to the unknowns until the magnitude of the corrections are insignificant through the application of a set of observation equations derived from Equation 1 through partial differentiation. The correction equations are:

$$\begin{aligned} v_x = [\, & p_{11} + (p_{12} + S_1 T_2)\,\Delta\omega + (p_{13} + S_1 T_3)\,\Delta\varphi + (p_{14} + S_1 T_4)\,\Delta K \\ & - p_{15}\,\Delta X_0 - p_{16}\,\Delta Y_0 - (p_{17} - S_1 T_7)\,\Delta Z_0 \\ & + p_{15}\,\Delta X + p_{16}\,\Delta Y + (p_{17} - S_1 T_7)\,\Delta Z]/\mathbf{A}_3\cdot\mathbf{B} \\ v_y = [\, & p_{21} + (p_{22} + S_2 T_2)\,\Delta\omega + (p_{23} + S_2 T_3)\,\Delta\varphi + (p_{24} + S_2 T_4)\,\Delta K \\ & - p_{25}\,\Delta X_0 - p_{26}\,\Delta Y_0 - (p_{27} - S_2 T_7)\,\Delta Z_0 \\ & + p_{25}\,\Delta X + p_{26}\,\Delta Y + (p_{27} - S_2 T_7)\,\Delta Z]/\mathbf{A}_3\cdot\mathbf{B}. \qquad (4) \end{aligned}$$

Expressions for evaluating the p-terms are given in table 1. The other terms are:

$$T_2 = \begin{vmatrix} X - X_0 \\ (\partial \mathbf{A}_1{}^T/\partial\omega)\,\mathbf{C} \end{vmatrix} \begin{vmatrix} Z - Z_0 \\ (\partial \mathbf{A}_3{}^T/\partial\omega)\,\mathbf{C} \end{vmatrix}$$

$$T_3 = \begin{vmatrix} X - X_0 \\ (\partial \mathbf{A}_1{}^T/\partial\varphi)\,\mathbf{C} \end{vmatrix} \begin{vmatrix} Z - Z_0 \\ (\partial \mathbf{A}_3{}^T/\partial\varphi)\,\mathbf{C} \end{vmatrix}$$

$$T_4 = \begin{vmatrix} X - X_0 \\ (\partial \mathbf{A}_1{}^T/\partial K)\,\mathbf{C} \end{vmatrix} \begin{vmatrix} Z - Z_0 \\ (\partial \mathbf{A}_3{}^T/\partial K)\,\mathbf{C} \end{vmatrix}$$

$$T_7 = \mathbf{A}_1{}^T\mathbf{C}\,(= x^*)$$

$$\mathbf{C} = \begin{bmatrix} x_2 \\ y_2 \\ z_2 \end{bmatrix}$$

$$S_1 = (1/u_2)\,(p_{15}\,u_3 + p_{16}\,u_4 + p_{17})$$

$$S_2 = (1/u_2)\,(p_{25}\,u_3 + p_{25}\,u_4 + p_{27})$$

$$u_3 = x^{*\prime}/z^{*\prime} \qquad u_4 = y^{*\prime}/z^{*\prime}$$

$$u_2 = x^{*\prime\prime} - u_3\,z^{*\prime\prime}$$

$$u_1 = Z_0''\,x^{*\prime\prime} - X_0''\,z^{*\prime\prime} + X_0'\,z^{*\prime\prime} - Z_0'\,u_3 z^{*\prime\prime}. \qquad (5)$$

Table 1.–The coefficients for the observation Equation 4.

$$p_{11} = \begin{vmatrix} x & z \\ \mathbf{A}_1\mathbf{B} & \mathbf{A}_3\mathbf{B} \end{vmatrix} \qquad p_{21} = \begin{vmatrix} y & z \\ \mathbf{A}_2\mathbf{B} & \mathbf{A}_3\mathbf{B} \end{vmatrix}$$

$$p_{12} = \begin{vmatrix} x & z \\ \frac{\partial \mathbf{A}_1}{\partial\omega}\mathbf{B} & \frac{\partial \mathbf{A}_3}{\partial\omega}\mathbf{B} \end{vmatrix} \qquad p_{22} = \begin{vmatrix} y & z \\ \frac{\partial \mathbf{A}_2}{\partial\omega}\mathbf{B} & \frac{\partial \mathbf{A}_3}{\partial\omega}\mathbf{B} \end{vmatrix}$$

$$p_{13} = \begin{vmatrix} x & z \\ \frac{\partial \mathbf{A}_1}{\partial\varphi}\mathbf{B} & \frac{\partial \mathbf{A}_3}{\partial\varphi}\mathbf{B} \end{vmatrix} \qquad p_{23} = \begin{vmatrix} y & z \\ \frac{\partial \mathbf{A}_2}{\partial\varphi}\mathbf{B} & \frac{\partial \mathbf{A}_3}{\partial\varphi}\mathbf{B} \end{vmatrix}$$

$$p_{14} = \begin{vmatrix} x & z \\ \frac{\partial \mathbf{A}_1}{\partial K}\mathbf{B} & \frac{\partial \mathbf{A}_3}{\partial K}\mathbf{B} \end{vmatrix} \qquad p_{24} = \begin{vmatrix} y & z \\ \frac{\partial \mathbf{A}_2}{\partial K}\mathbf{B} & \frac{\partial \mathbf{A}_3}{\partial K}\mathbf{B} \end{vmatrix}$$

$$p_{15} = \begin{vmatrix} x & z \\ a_{11} & a_{31} \end{vmatrix} \qquad p_{25} = \begin{vmatrix} y & z \\ a_{21} & a_{31} \end{vmatrix}$$

$$p_{16} = \begin{vmatrix} x & z \\ a_{12} & a_{32} \end{vmatrix} \qquad p_{26} = \begin{vmatrix} y & z \\ a_{22} & a_{32} \end{vmatrix}$$

$$p_{17} = \begin{vmatrix} x & z \\ a_{13} & a_{33} \end{vmatrix} \qquad p_{27} = \begin{vmatrix} y & z \\ a_{23} & a_{33} \end{vmatrix}$$

[11]Harris, Tewinkel, and Whitten, see footnote 1.

All of the terms in Equation 4 are never used at the same time. For example, the S- and T-terms are used only in the initial pair of the first triplet; ΔX_0, ΔY_0, ΔZ_0 do not apply to some classes of images and ΔX, ΔY, ΔZ do not apply to others.

The corresponding equations of Technical Bulletin No. 21[12] were modified in order to make them applicable to the three-photo solution. One of the principal modifications of these equations is that each photograph (except the initial one of the strip) is considered to be tilted a specified amount in the three-photo system, whereas in the two-photo system, the initial photograph of each stereo pair is considered always to be untilted. Consequently, $x^{*'}$ and $x^{*''}$ represent "rectified" image coordinates on the left and right of two overlapping photographs, respectively.

Another modification of the aforementioned equations has to do with the photograph base. In the two-photo system, the base length is assigned arbitrarily the value 1 with a consequent simplification in formulation, but in the three-photo system, each base distance differs numerically. Accordingly, the "intersection" formulas now have a general form as indicated by the expression for the u's in Equation 5.

The first approximation for the coordinates of an object can be determined by computing the point of intersection of two directed lines in space, as related to the camera parameters of the two photographs on which the images appear. The formulas denoting the coordinates of the point of intersection are:

$$Z = u_1/u_2$$
$$X = X_0' + u_3(Z-Z_0')$$
$$Y = Y_0' + u_4(Z-Z_0') . \qquad (6)$$

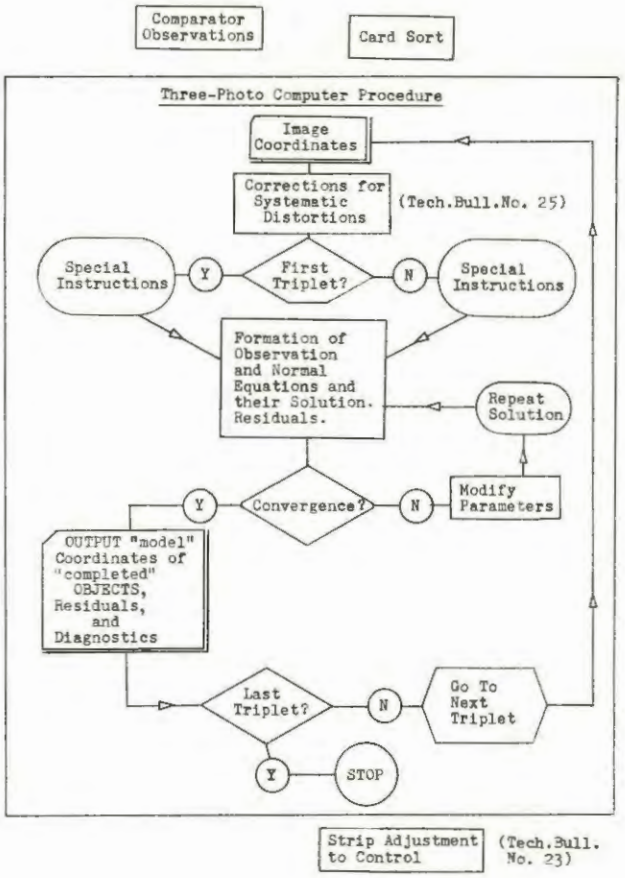

FIG. 1.--A generalized flow chart showing the sequence of the computational procedure for the three-photo solution.

THE SCHEME OF THE SYSTEM

The scheme and logic of the three-photo solution is described by means of a series of explanations. Figure 1 is a generalized flow chart.

1. The refinement corrections are applied to the coordinates from each new photograph, one at a time, as the data are input for each new separate triplet.

2. The first three photographs of a strip are treated as an initial unit, somewhat differently from all the other triplets.

First Triplet

3. The first photograph of the strip is considered to be "untilted" ($\omega = \varphi = K = 0$).

4. The first camera station is considered to have the coordinate $X_0 = Y_0 = Z_0 = 0$.

5. The X_{02}-coordinate of the second camera station of the first triplet (only) is *fixed* so that it is equal to the x-coordinate on the *first* photograph of a pass point which is near the center of the *second* photograph. This determines the "model" scale of the strip coordinate system, and makes the scale nominally equal to the scale of the photography.

6. The first approximation for the other parameters of the second and third photographs of the first triplet are:

$$\omega_2 = \varphi_2 = K_2 = Y_{02} = Z_{02} = 0$$

$$\omega_3 = \varphi_3 = K_3 = Y_{03} = Z_{03} = 0 .$$

7. The first approximation for the X_{03}-coordinate of the third camera station is equal to that for the X_{02}-coordinate, plus the x-coordinate on the *second* photograph of a pass point which is near the center of the *third* photograph.

8. The solution determines the adjusted values for all the variable parameters, not only for the camera stations, but also for the X-, Y-, Z-model coordinates of all the pass points, other points, and control point images (but geodetic control data are not administered at this stage of the computation).

[12] Ibid.

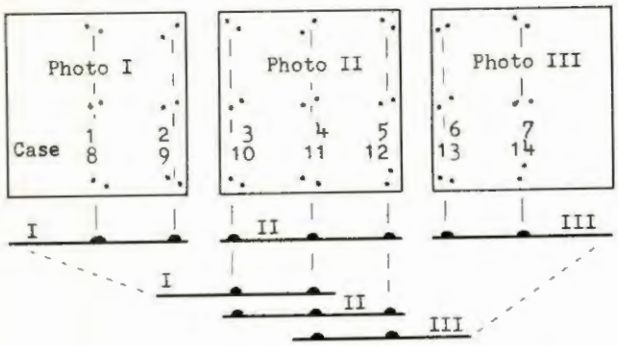

FIG. 2.--Three overlapping photographs, the pass point image locations, and the identification of the 14 categories (cases) of points.

Subsequent Triplets

9. If the photograph numbers of the previous triplet are $(n-1)$, n, $(n+1)$, the photograph number for the next triplet would be n, $(n+1)$, $(n+2)$.

10. The solution for the parameters ω, φ, K, X_0, Y_0, Z_0 of the middle photograph n in the previous triplet is considered as final and is held fixed in the solution that follows. As a consequence, the special cantilever program, used formerly, is not required.

11. The model coordinates X, Y, Z of the six pass points across the center (perpendicular to the line of flight) of the n-th photograph in the previous triplet are considered as final and are used somewhat like ground control points for adjusting the next triplet. As a consequence, a single coordinate system is carried forward continuously throughout the entire length of the strip. It is also noteworthy that *all six* points are used.

12. The first approximations for the parameters of photograph $(n+1)$ are the resultant values of the previous triplet. These will receive small additional modifications.

13. The first approximations for the parameters ω, φ, K, Y_0, Z_0 of the new third or $(n+2)$ photograph are set equal to the corresponding parameters of the $(n+1)$ photograph.

14. The first approximation for the parameter X_0 of the $(n+2)$ photograph is derived in the same manner as described in paragraph 6.

15. After each triplet is computed, all final data concerning the first photograph are printed out in order to vacate memory storage space for the next triplet solution.

16. The first approximations are determined once for every object through the use of the intersection formulas of Equation 6.

17. The first approximations for the six parameters of the second photograph of a new triplet are the final values that they had at the end of the previous triplet.

18. To form a new triplet, the stored data for the second and third photographs of the old triplet are "moved over" into the locations for the first and second photographs; then the new data for the third photograph become input, and the new image coordinates are refined.

19. The first approximations for the five camera parameters (the sixth is specified by paragraph 6) are taken as *those of the preceding photograph* rather than as zeros.

It is pertinent to the application of the system that (1) the input data are sorted into a very definite sequence prior to the computation, and (2) the application of ground control data comprise a completely separate computation (strip adjustment).[13]

THE "CASE" CONCEPT

As a consequence of the foregoing scheme for the three-photo system, it becomes convenient, if not necessary, to establish a "case" technique in order to recognize the different ways to manipulate the coordinate data from the various pass point locations. Figure 2 depicts the geometric situation.

The three photographs have the customary overlap of 60 percent. Two pass points are selected in each of three locations across the center of each photograph so that the pass points are common to and appear eventually on all triplets (three overlapping photographs), except for the first and last photograph of a strip. Thus, 7 groups of 6 points each are considered as constituting 14 *cases*, not all distinct. Several of the cases differ for the initial and subsequent triplets. The cases are designated in the Fortran program through the use of an index number which is called IGO.

A case refers to the presence or absence of certain terms in the pair of observation Equation 4, repeated in slightly different form as follows:

$$\begin{aligned}
&(p_{12} + S_1 T_2)\ \Delta\omega + (p_{13} + S_1 T_3)\ \Delta\varphi + (p_{14} + S_1 T_4)\ \Delta K \\
&\quad - p_{15}\ \Delta X_0 - p_{16}\ \Delta Y_0 - (p_{17} - S_1 T_7)\ \Delta Z_0 \\
&\quad + p_{15}\ \Delta X + p_{16}\ \Delta Y + (p_{17} - S_1 T_7)\ \Delta Z = -p_{11} \\
&(p_{22} + S_2 T_2)\ \Delta\omega + (p_{23} + S_2 T_3)\ \Delta\varphi + (p_{24} + S_2 T_4)\ \Delta K \\
&\quad - p_{25}\ \Delta X_0 - p_{26}\ \Delta Y_0 - (p_{27} - S_2 T_7)\ \Delta Z_0 \\
&\quad + p_{25}\ \Delta X + p_{26}\ \Delta Y + (p_{27} - S_2 T_7)\ \Delta Z = -p_{21}\ .
\end{aligned} \tag{7}$$

It is understood that all the coefficients are divided by a common product A_3B which is omitted intentionally in this discussion in the interest of simplicity, but is included in the program. It is noted also that the ST-terms occur in Case 3.

Each case is now to be discussed. The initial triplet embodies Cases 1 through 7; subsequent triplets use Cases 8 through 14. The cases are summarized in table 2.

Initial Triplet

Case 1.

Case 1 is a null case in which all the coefficients are zeros; consequently, nothing is con-

[13]Keller and Tewinkel, see footnote 2.

Table 2.–Categories of observation equations.

Case	IGO	Unknowns: $\Delta\omega, \Delta\varphi, \Delta K, \Delta Y_0, \Delta Z_0$	Unknowns: ΔX_0	Unknowns: $\Delta X, \Delta Y, \Delta Z$	Intersection routine
INITIAL TRIPLET					
Photo I.					
1	--	0	0	0	0
2	3	0	0	1	1
Photo II.					
3	1	1	0	0	1*
4	2	1	0	1	0
5	5	1	0	1	1
Photo III.					
6	4	1	1	1	0
7	6	1	1	1	0
SUBSEQUENT TRIPLETS					
Photo I.					
8	--	0	0	0	0
9	3	0	0	1	0
Photo II.					
10	1	1	1	0	0
11	2	1	1	1	1
12	5	1	1	1	1
Photo III.					
13	4	1	1	1	0
14	6	1	1	1	0

*In this single instance, the intersection routine is applied repeatedly on each iteration; on all other occasions, it is applied only on the first iteration of a triplet. Also, Case 3 is the only case in which the *ST*-terms apply.

tributed to the computation. The three angular and three linear parameters of the camera station for Photo I are assigned the value zero and are not permitted to be adjusted; therefore, $\Delta\omega$, etc. are also zeros. The object coordinates X, Y, Z are derived later during Case 3.

Case 2.

Equation 7 is expressed in the following simplified form as:

$$p_{15}\ \Delta X + p_{16}\ \Delta Y + p_{17}\ \Delta Z = -p_{11}$$

$$p_{25}\ \Delta X + p_{26}\ \Delta Y + p_{27}\ \Delta Z = -p_{21}$$

The images for Case 2 are on Photo I which, as in Case 1, have assigned to it zeros for all six of the camera parameters. But the object coordinates ΔX, etc. are adjusted through the least-squares computation. The *ST*-terms in ΔZ do not apply because those terms are designed for application whenever ΔX, ΔY, ΔZ are eliminated through substitution, instead of the least-squares computation which is applied in this case. In the first iteration, approximate values for X, Y, Z are determined through the intersection routine.

Case 3.

The form of the observation equation is:

$$(p_{12} + S_1 T_2)\ \Delta\omega'' + (p_{13} + S_1 T_3)\ \Delta\varphi'' + (p_{14} + S_1 T_4)\ \Delta K'' - p_{16}\ \Delta Y_0'' - (p_{17} - S_1 T_7)\ \Delta Z_0'' = -p_{11}$$

$$(p_{22} + S_2 T_2)\ \Delta\omega'' + (p_{23} + S_2 T_3)\ \Delta\varphi'' + (p_{24} + S_2 T_4)\ \Delta K'' - p_{26}\ \Delta Y_0'' - (p_{27} - S_2 T_7)\ \Delta Z_0'' = -p_{21}\,.$$

As these images are on Photo II, the camera parameters are allowed to vary, except for $\Delta X_0''$ which is the air base fixed arbitrarily at the observed distance on the diapositive. The adjustments ΔX, ΔY, ΔZ do not occur because they are eliminated through the use of the *ST*-increments. The object coordinates X, Y, Z are derived through the application of the intersection formulas of Equation 6 for each repetition of the least-squares solution. This is the *only* case where (1) the *ST*-terms apply, and (2) the intersection formulas are used repeatedly.

Case 4.

All the parameters except $\Delta X_0''$ are present in the observation equations as follows:

$$p_{12}\ \Delta\omega'' + p_{13}\ \Delta\varphi'' + p_{14}\ \Delta K'' - p_{16}\ \Delta Y_0'' - p_{17}\ \Delta Z_0'' + p_{15}\ \Delta X + p_{16}\ \Delta Y + p_{17}\ \Delta Z = -p_{11}$$

$$p_{22}\ \Delta\omega'' + p_{23}\ \Delta\varphi'' + p_{24}\ \Delta K'' - p_{26}\ \Delta Y_0'' - p_{27}\ \Delta Z_0'' + p_{25}\ \Delta X + p_{26}\ \Delta Y + p_{27}\ \Delta Z = -p_{21}\,.$$

The initial approximations for X, Y, Z, obtained previously during Case 2, are not repeated in this case.

Case. 5.

The observation equations are exactly identical to those for Case 4. The initial approximations of X, Y, Z are computed with intersection formulas only in the first iteration of the triplet solution.

Case 6.

The observation equations contain all nine unknowns, including ΔX_0. The camera parameters apply to Photo III instead of Photo II heretofore as:

$$p_{12}\ \Delta\omega''' + p_{13}\ \Delta\varphi''' + p_{14}\ \Delta K''' - p_{15}\ \Delta X_0''' - p_{16}\ \Delta Y_0''' - p_{17}\ \Delta Z_0''' + p_{15}\ \Delta X + p_{16}\ \Delta Y + p_{17}\ \Delta Z = -p_{11}$$

$$p_{22}\ \Delta\omega''' + p_{23}\ \Delta\varphi''' + p_{14}\ \Delta K'''$$
$$- p_{25}\ \Delta X_0''' - p_{26}\ \Delta Y_0''' - p_{27}\ \Delta Z_0'''$$
$$+ p_{25}\ \Delta X + p_{26}\ \Delta Y + p_{27}\ \Delta Z = - p_{21}\ .$$

Initial approximations of X, Y, Z are not computed in this case because they were computed previously in Case 2.

Case 7.

Case 7 has the same observation equations as Case 6. The initial approximations for X, Y, Z were computed previously during Case 5.

This is the last of the cases that pertains to the initial triplet. The cases that follow apply to all the subsequent triplets.

Subsequent Triplets

With the completion of the previous triplet, the data for Photo II are transferred into the memory area of Photo I, the matching data for Photo III are transferred into the former area of Photo II, and the corresponding data for a new photograph added to the strip are read into the previous area of Photo III.

Incidentally, *no ST*-terms are used in the subsequent triplets, and the intersection routine is employed *only* in Case 12.

Case 8.

Case 8, like Case 1, is the null case which requires no computer operation. The three angular and three linear parameters of the camera for the new Photo I are assigned the final values which they had in the previous triplet and are not allowed to change any more. Similarly, the X, Y, Z values of all six objects are considered to be final and are not allowed any further changes; they serve to establish the linear scale and direction of the triplet.

Case 9.

Case 9 is almost identical to Case 2. As the images are on Photo I, which is "frozen," the camera adjustments must be zeros and only the object coordinates are allowed to be adjusted further.

Case 10.

The object coordinates are fixed at the final values that they had in the previous triplet, and the six camera parameters (including the air base) for the new Photo II are allowed to change as indicated by the observation equations:

$$p_{12}\ \Delta\omega'' + p_{13}\ \Delta\varphi'' + p_{14}\ \Delta K''$$
$$- p_{15}\ \Delta X_0'' - p_{16}\ \Delta Y_0'' - p_{17}\ \Delta Z_0'' = - p_{11}$$

$$p_{22}\ \Delta\omega'' + p_{23}\ \Delta\varphi'' + p_{24}\ \Delta K''$$
$$- p_{25}\ \Delta X_0'' - p_{26}\ \Delta Y_0'' - p_{27}\ \Delta Z_0'' = - p_{21}\ .$$

Case 11.

The observation equations for Case 11 include the object coordinates as follows:

$$p_{12}\ \Delta\omega'' + p_{13}\ \Delta\varphi'' + p_{14}\ \Delta K''$$
$$- p_{15}\ \Delta X_0'' - p_{16}\ \Delta Y_0'' - p_{17}\ \Delta Z_0''$$
$$+ p_{15}\ \Delta X + p_{16}\ \Delta Y + p_{17}\ \Delta Z = - p_{11}$$

$$p_{22}\ \Delta\omega'' + p_{23}\ \Delta\varphi'' + p_{24}\ \Delta K''$$
$$- p_{25}\ \Delta X_0'' - p_{26}\ \Delta Y_0'' - p_{27}\ \Delta Z_0''$$
$$+ p_{25}\ \Delta X + p_{26}\ \Delta Y + p_{27}\ \Delta Z = - p_{21}\ .$$

The program includes the intersection routine even though it is not a requirement.

Case 12.

The observation equations for Case 12 are exactly the same as the preceding ones for Case 11. The intersection routine is applied only during the first iteration of the triplet. This is the only case for subsequent triplets in which the intersection routine is applied.

Case 13.

Case 13 is identical to Case 6 in every way, except that the initial approximations of X, Y, Z are not computed in this case because they were computed previously.

Case 14.

Finally, Case 14 is also identical to Case 6.

The program is based on a strict observance of the system adopted for the selection and numbering of pass points. If suitable images do not exist in their customary locations, the total number is, nevertheless, selected in other locations, as long as they appear on all three photographs.

Photograph No. 19

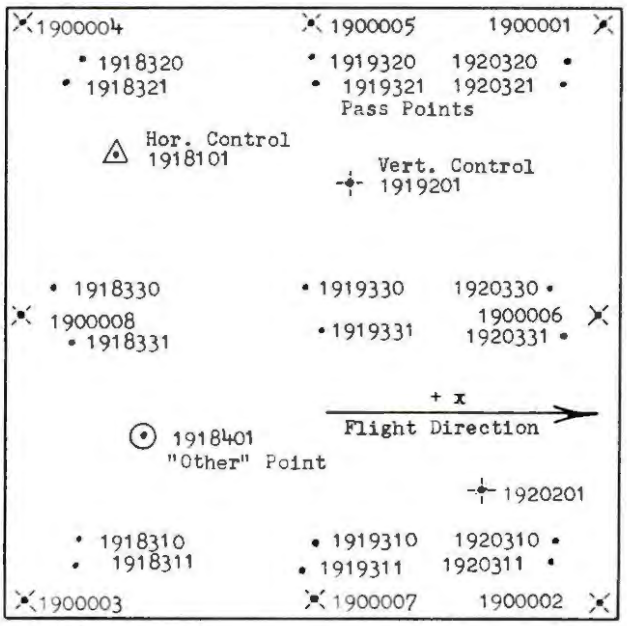

FIG. 3.--The system of numbering the images on a photograph.

Not only is a rigid system adopted for assigning identification numbers to the images, but also the coordinates are observed with the comparator in a given sequence that includes fiducial marks, control points, and "other" points in addition to the pass points. A special card sorting operation also is applied in order to have the input cards in the proper order for computation. The numbering system and storage order help explain how the case and system are employed. Figure 3 illustrates the image-numbering system. A seven-digit image identification number is used, for example, 1918331. The various digits have the following significance:

Digits 1 and 2. The last two digits (19) are those of the serial number of the photograph on which the coordinates are measured.

Digits 3 and 4. The last two digits (18) are those of the serial number of the photograph whose center is nearest the image.

Digit 5. The image class digit (3) denotes:
- 0 = fiducial mark,
- 1 = horizontal control point,
- 2 = vertical control point,
- 3 = orientation pass point,
- 4 = "other" point (not used in the orientation adjustment).

Digit 6. The subclass digit (3) of the orientation pass point designating location in the strip connotes that:
- 1 = y-coordinate is minimum,
- 2 = y-coordinate is maximum,
- 3 = y-coordinate indicates center of strip.

Digit 7. The serial number digit (1) is that for a point within its class: As an example, for Class 3, 330 is a pass point and 331 is its companion pass point.

A sample list of input data (app. 1), reproduced on pages 16 to 25, illustrates the form and order of the image coordinate data. The three columns of numbers are the image-identification number, the x-coordinate, and the y-coordinate. (The decimal point for the coordinates is on the extreme left, the unit of measurement is meters, and the values are given to tenths of microns derived by averaging several observations.)

The order of the image class is pertinent. (*See also* the division on "Input Formats," p. 10.) The fiducial marks (Class 0) are listed first, either 4 or 8 of them may be employed; exactly 18 pass points (Class 3) are given next; and the remainder, up to 32 additional points, are recorded later in any order (Classes 1, 2, and 4) because those additional points are not used in the orientation adjustment although they are transformed later as a result of the adjustment.

The fact that exactly 18 pass points are implied necessitates the use of dummy zero cards for those images that are not observed because the points appear on only 2 photographs--the first and last photographs of a strip.

The image coordinates are stored in a B-array, containing 50 rows and 9 columns, as specified by a Fortran DIMENSION statement. Three columns are allocated to each of the three photographs in any triplet (the data are "moved over" before beginning the next triplet).

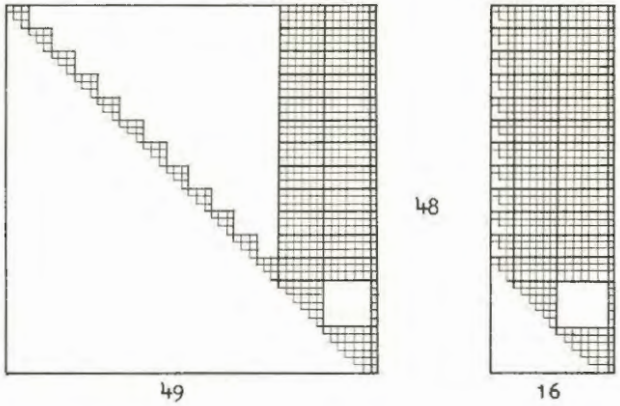

FIG. 4.--The compression of the matrix of normal equations.

The first 18 rows contain the pass point data. The 18 rows are composed of 3 sets of 6 rows each. The order of storage of these 18 items is pertinent and is indicated by the order of the pass point identification number shown in the sample list of input data. Note that nine sets of data for six points are evident--three are attributed to each photograph. It is probably evident that the first and ninth sets are not used in this triplet because these points appear only on one photograph of the triplet. The remaining 7 sets are pertinent: *they constitute the basis for 14 cases in a strict sequence.*

It is also pertinent that, given an image in the *13th* row for the *first* photograph, the data for the corresponding image on the *second* photograph are stored in the *7th* row (13 minus 6) of the second group of three columns; in addition, the data for the corresponding image on the *third* photograph are stored in the *1st* row (13 minus 12) of the third group of three columns.

MATRIX COMPRESSION

The matrix or table for the normal equations and their solution is condensed in this section as an exercise in developing a general scheme which, although perhaps not necessarily required for a three-photo solution, is considered mandatory for the solution of the larger problems that are planned for the near future. The subject also has been discussed recently by Mr. Ronald G. Davis.[14]

Figure 4 depicts the matrix situation. On the left side is shown the 49-by-48 word area that would be necessary to solve the problem in the conventional manner. However, this program uses only a 16-by-48 word area, reducing the required storage space from 2,352 to 768 words, as shown on the right side of the figure. This compression is possible because of (1) the predominant section of uninterrupted zeros in the

[14] Analytical adjustment of large blocks by Ronald G. Davis, *Photogrammetric Engineering*, vol. 32, no. 1, pp. 87-97, January 1966.

system, and (2) the sequence and scheme selected for forming the observation equations. Actually, the only difference between the programs for the classical and compressed systems has to do with the modification of selected subscript numbers, denoting the row and column in which certain terms are stored.

The 48 unknowns consist of an adjustment to each of the 3 rectangular coordinates of the 12 pass points that are free to change, and an adjustment to each of the 6 parameters in each of the 2 free photographs.

Each image on every photograph gives rise to two observation equations (Equation 4). Once the coefficients for a pair of observation equations are computed, their contributions to the system of normal equations are accumulated into that system and then the observation equations are replaced by the next pair. The basic scheme for the formation and solution of the normal equations was stated previously.[15]

The 3 coordinate changes, ΔX, ΔY, ΔZ for each of the 12 objects, are selected as the primary arguments for storing the elements of the normal equations; these coordinate changes are placed in the 36-by-3 word area on the left side of the compressed system.

The compressed matrix can be considered as being composed of four areas. Area 1 is the 36-by-3 word area previously mentioned. Area 2 is the single column of 48 numbers on the right side, comprising the list of constant terms. Area 3 is the 36-by-12 word area that lies between Areas 1 and 2. Area 4 is the 12-by-12 word area at the bottom which also contains a 6-by-6 word area, composed of zeros initially but also filled with significant numbers subsequently as the forward solution is begun.

Areas 1, 2, and 3 are subdivided into 12 sets of 3 rows each. Each set is associated with an *object* and its coordinate corrections ΔX, ΔY, ΔZ. Each of these sets is, in a sense, independent from the other 11 sets, and the forward solution of each set deposits values into Area 4 without reference to the preceding or succeeding set. Moreover, in the back solution, each set is again independent from the others, depending only on the results stored in Area 4. It is possible to take advantage of this independence in large systems of the future through the incorporation of "scratch" tape or disc memory to augment the core storage, although such is not necessary in this three-photo problem.

A significant burden of the solution consists of the forward solution, contained in the 12-by-13 matrix of Area 4, which may be considered as a comparatively small problem rather than a large one. The 36-object unknowns (ΔX, ΔY, ΔZ) do not constitute a large computing burden because of their independence, as indicated by the zeros in the classical matrix. Neither computer speed nor rounding errors become important factors in this size-limited problem, partly because of the large computer being used. In this instance, double precision is not needed because of the word length of the STRETCH computer. Moreover, the coefficients for the observation equations are recomputed for each iteration of the adjustment, although this may not be necessary on the last iteration.

As in the classical system, all the "answers" are recorded finally in Area 2.

DIMENSIONED ARRAYS

The computation is facilitated by the utilization of six arrays established through the use of a Fortran DIMENSION statement, five of which are illustrated by Figure 5 and are enumerated as follows:

A. (50 by 16). The compressed normal equations. Parts of the area are used also for several of the following functions whenever the area is not being used for its primary purpose: (1) The formation and storage of the film-shrinkage observation equations; (2) the formation and solution of the film-shrinkage normal equations; (3) the meaning of multiple-image coordinate observations underneath the 12-by-12 diagonal word area; (4) the storage of the u-terms (Equation 5); (5) the S- and T-terms (Equation 5);

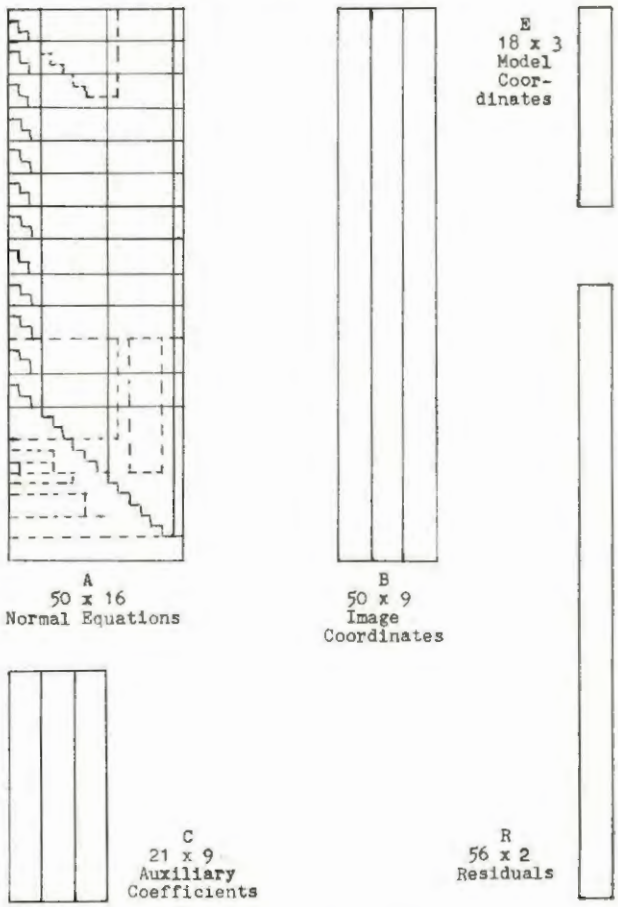

FIG. 5.--The five arrays of core storage.

[15]Keller and Tewinkel, p. 6, see footnote 2.

(6) the allowable limit for residual parallax; (7) the photograph and strip constants; (8) the coefficients of two observation equations for the triplet; and (9) the place for rearranging the coefficients of the observation equations to fit the case distinctions prior to the normal equation contribution.

B. (50 by 9). Identification numbers and coordinates for all classes of images in the three photographs.

C. (21 by 9). Auxiliary trigonometric data for the formation of the coefficients of observation equations in all three photographs.

E. (18 by 3). The 3 space-model coordinates of the 18 pass point objects.

R. (56 by 2). Image-identification number and x- and y-residual errors (parallaxes).

T. (151 by 1). Radial lens-distortion table.

INPUT FORMATS

A sample set of input data is included in appendix 1. This comprises a set of valid operational material which results in the output data shown in appendix 3, through the application of the program given in appendix 2.

The input consists of standard 80-column IBM punch cards.

Eight READ statements are used and five FORMAT statements are specified in the input program. These statements are described in the following list.

```
1.   350 READ 500                          (004)*
     500 FORMAT (55H. . . )                (663)
```

One Card: Job title, etc.; 55 alphameric characters, beginning in the first column.

```
2.        READ 508 (A(42, J), J=1, 2),
          A(41, 1), A(41, 5)               (006)
     508 FORMAT (2F10.7, F10.6, 1X, I1)    (672)
```

One card of four *strip* constants:

2.1 and 2.2--The atmospheric refraction factors.

2.3--The parallax limit. A pass point image is deleted if the residual exceeds this arbitrary limit.

2.4--An indicator for block adjustment. If the block is to follow, the refined-image coordinates are output; otherwise not.

The camera-constants deck consists of formats 3, 4, and 5, and includes 15 or 19 cards, depending on whether 4 or 8 fiducial marks are used.

```
3.        READ 501, N, (A(42, J), J = 3, 6)  (007)
     501 FORMAT (1X, I3, 4(2X, E12.8))       (664)
```

One card, five words:

3.1--The number of fiducial marks (four or eight).

3.2, 3.3, and 3.4--The constants for the asymmetric lens-distortion compensation.

3.5--The calibrated focal length (in same units as image coordinates) of the aerial camera lens. (The unit in the example is the meter.)

```
4.        READ 502, (A(I + 30, 1),
          (A(I + 30, J + 1), J = N, NP1),
          ITEST, I=1, N)                   (011)
     502 FORMAT (3X, I7, 2F10.7, 49X, I1)  (665)
```

Four or eight cards, as specified in the first word of the previous card.

4.1--The fiducial-mark identification number.

4.2 and 4.3--The x- and y-coordinates of a fiducial mark. The values are (1) based on measurements made on glass plates exposed directly in the camera, (2) referred to the principal point as origin, (3) adjusted to include corrections for calibration constants of the comparator, and (4) stated in the example to seven decimals of a meter.

```
5.        READ 503, (T(I), I = 1, 151)     (012)
     503 FORMAT (15F5.1)                   (666)
```

Eleven cards, containing the 151 symmetrical radial-distortion factors, are effective at each 1-millimeter radius. Each factor is stated to 5 digits in fixed-point mode, and 15 factors are punched on each card, except the last card which contains only 1 number.

```
6.        READ 502, IPLATE                 (021)
     502 FORMAT (3X, I7, 2F10.7,
          49X, I1)                         (665)
```

One number, containing from one to seven digits, identifies the photograph being processed.

```
7.   204 READ 502, (A(I, J), J = 12, 14),
          ITEST                            (025)
     502 FORMAT (3X, I7, 2F10.7,
          49X, I1)                         (665)
```

Image coordinates, numerous cards, one card per image, and four words:

7.1--The image-identification number.

7.2 and 7.3--The x- and y-image coordinates. These coordinates are stated in terms of a meter to seven decimals.

7.4--A number 1 in column 80 of a fiducial-mark card. This signifies the last card for that photograph.

Input 7 is used twice for each photograph. Firstly, the four or eight fiducial-mark coordinates are input, and the various factors (line 134 in this program and Equations 1 and 2 of Technical Bulletin No. 25)[16] for coordinate refinement are computed. Secondly, the coordinates of the photographic images (nonfiducial images) are all read in--the 18 pass points first, then all the other classes of images in any order. In both

*The numbers on the right side refer to the corresponding serial numbers in the Fortran program of appendix 2. These numbers are key punched in the source program deck after column 72 and, therefore, do not become a part of the program.

[16]Keller and Tewinkel, p. 2, see footnote 3.

series of cards, there may be from 1 to 10 cards for each image, and all the cards must be together.

The sample input data shown in appendix 1 has received some preliminary processing so that the input cards consist of the average value to tenths of microns of the several comparator observations. Ordinarily, the input has all zeros in the last column as shown in Technical Bulletin No. 25.[17]

```
8.  352 READ 518, I10, I80                (649)
    518 FORMAT (I10, 69X, I1)             (684)
```

One terminator card having: (1) A number 1 punched in column 80, or (2) no number punched at all (a blank card). The card with the number 1 punched in column 80 must follow the last image-coordinate card for each photograph. The blank card must follow the last input card of the last photograph for the strip. In this example, the message END OF STRIP INPUT DATA is punched between columns 11 and 79 so that the information appears in the list of the input data, but is not recognized as input to the computations.

OUTPUT FORMATS

A sample output is shown as appendix 3. Each PRINT and PUNCH statement of the Fortran program (app. 2) is described briefly by the following Output statements in that order, respectively. Reference numbers (on the right side) key the statements to the program.

```
1.          PRINT 500                     (005)
    500 FORMAT (55H...)                   (663)
```

The identifying name of the project or any other information is output in the same form in which it is input.

```
2.  203 PRINT 504                         (028)
    504 FORMAT (78H MEASURED
        FIDUCIAL MARK CARDS NOT
        IN SEQUENCE OR 2 BAD READ-
        INGS ON POINT-STOP)               (667)
```

The error message is considered to be self-explanatory. The message is the result of a failure to satisfy a test. The input data must be in the proper order. Moreover, in a list of multiple observations on the same mark, only one observation deviates from the mean by more than 25 microns.

```
3.  218 PRINT 505, IPLATE, A(31, 12)      (065)
    505 FORMAT (38H DEV FROM
        MEAN OVER 25 MICRONS.
        PLATE I7, 7H POINT I7)            (669)
```

This error message identifies the erroneous data.

```
4.  342 PRINT 514, R(I, 1), R(I, 2)       (438)
    514 FORMAT (/15H XPARALLAX
        FOR I7, 4H IS E14.8, 18H AND
        EXCEEDS LIMIT)                    (679)
```

This statement and the next one indicate a failure to pass a test limit specified in the Input statement 006. The image is identified as being deleted so that it will not be used later in mapping.

```
5.  339 PRINT 507, R(I, 1), R(I, 2)       (440)
    507 FORMAT (/15H YPARALLAX
        FOR I7, 4H IS E14.8, 18H AND
        EXCEEDS LIMIT)                    (671)
```

The limit is specified by Input statement 006. Those images that appear on only two photographs have valid y-parallax values but invalid x-parallax values.

```
6.  185 PRINT 511                         (447)
    511 FORMAT (52H TWO BAD
        RESIDUAL PARALLAXES IN
        SAME LOCATION. STOP)              (675)
```

The test assures that the six conventional image locations are used always in the solution of every model orientation.

```
7.  184 PRINT 513                         (449)
    513 FORMAT (53H THREE BAD
        RESIDUAL PARALLAXES IN
        SAME TRIPLET. STOP)               (678)
```

Substandard precision is considered to be evident if 3 images (one-fourth of the total of 12) fail to pass the input limit.

```
8.  168 PRINT 512                         (568)
    512 FORMAT (/71H...PASS PT...
        X...Y...Z...PRECISION/)           (676)
```

This comprises the column headings for the list to follow.

```
9.          PRINT 509, FK, (E(I, J),
            J = 1, 3), X                  (583)
    509 FORMAT (3X, I7, 4(2X, E14.8))     (673)
```

The output for those pass points that occur on three photographs consisting of (1) the image-identification number, (2) the x-model coordinate, (3) the y-model coordinate, (4) the z-model coordinate, and (5) the vector sum of all the x- and y-parallaxes. Except for the image-identification number, all coordinates and the vector sum are given in decimals of a meter in floating-point notation. The list is presented for the six new points for each model of the strip. (In the floating-point notation, for example, .10774661E-03 can be expressed as $.10774661 \times 10^{-3}$, or .00010774661 of a meter, or 107.74661 microns.)

```
10. 179 PRINT 509, FK, (E(I, J),
            J = 1, 3), R(I, 2)            (587)
    509 FORMAT (3X, I7, 4(2X, E14.8))     (673)
```

[17] Keller and Tewinkel, p. 8, see footnote 3.

This output is nearly identical to the previous one, except that it pertains to those points in the first and last models that fall on only two photographs, and therefore, have only the y-parallaxes as residuals.

```
11.        PRINT 510, R(55, 2)                    (594)
      510  FORMAT (29H RMS PARALLAX
           FOR TRIPLET IS E14.8/)                 (674)
```

The root-mean-square value of all the residual parallaxes for all the pass points of the triplet is stated as a reliability number in floating-point decimal of a meter.

```
12.  357   PRINT 515                              (596)
      515  FORMAT (/71H...OBJECT...
           X...Y...Z...PRECISION/)                (680)
```

The heading for the list of "other objects" distinguishes them from "pass points," as the objects do not enter into the computational adjustment.

```
13.        PRINT 509, FK, (E(1, J),
           J = 1, 3), Y                           (628)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

The output is essentially identical to that for Output statement 9. The precision refers to y-parallax only.

```
14.  358   PRINT 517                              (632)
      517  FORMAT (/33H...IMAGE...
           RESIDUAL X, Y PARALLAX/)               (683)
```

The heading for the residual parallaxes x and y is listed for all the pass points in a triplet as (1) a diagnostic tool in the event of difficulty, and (2) a relative reliability factor for applying a criterion to the use or nonuse of the points in mapping.

```
15.  258   PRINT 509, R(I, 1), R(I, 2)            (634)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

The list of numbers that follows the heading statement of the previous output.

```
16.        PRINT 516                              (636)
      516  FORMAT (/27H...NEW
           TRIPLET/)                              (682)
```

This statement serves as a divider between the outputs for separate triplets, except for the last triplet in which the additional data follow relative to those points in the last model that appear only on two photographs.

```
17.  355   PRINT 512                              (653)
      512  FORMAT (/71H...PASS PT...X
           ...Y...Z...PRECISION/)                 (676)
```

Heading for those pass points in the last model that appear only on two photographs.

```
18.        PRINT 509, FK, (E(I, J),
           J = 1, 3), R(I + 30, 2)                (658)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

Data for the heading of the previous PRINT statement are in the same format as Output statement 9.

```
19.  359   PRINT 519                              (661)
      519  FORMAT (/49H ** STRIP
           ANALYTIC AEROTRIANGULA-
           TION COMPLETED **/)                    (685)
```

A notice is printed indicating the end of the strip, and the computer is set to begin a new strip, if one is available.

PUNCH statements are applied to produce cards for two purposes: (1) A strip adjustment which always follows, and (2) a block adjustment which possibly may follow. Cards are used in order to arrange the data in a different order and to delete those items that may not be needed nor wanted. Punching is not done on the STRETCH computer, but is done in conjunction with the subsequent printing operation--using the IBM-1401 computer--from magnetic tape produced on the STRETCH computer.

```
20.  148   PUNCH 509, (B(I, J),
           J = NCOL, K)                           (167)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

The refined-image coordinates, once computed, need not be recomputed in a subsequent block adjustment. The format is explained in Output statement 9. The pertinent data are (1) the image-identification number, (2) the x-coordinate, and (3) the y-coordinate.

```
21.        PUNCH 509, FK, (E(I, J),
           J = 1, 3), X                           (584)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

These are the same pass points data as for Output statement 9; namely, (1) the image-identification number, (2) the X-, Y-, Z-model coordinates at photograph scale, and (3) the residual-error vector. The cards are used in the subsequent strip adjustment (not for the block).

```
22.        PUNCH 509, FK, (E(I, J),
           J = 1, 3), R(I, 2)                     (588)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

The "other objects" data are output by means of a separate statement as in Output statement 10, and for the same purpose as in Output statement 21.

```
23.        PUNCH 509, FK (E(I, J),
           J = 1, 3), R(I + 30, 2)                (659)
      509  FORMAT (3X, I7, 4(2X, E14.8))          (673)
```

A separate statement is required for those images that appear only on two photographs and that are in the last model.

THE FORTRAN PROGRAM

Appendix 2 comprises a list of the source program annotated with additional notes and including a serial number on the right side of each

line of the list. Notes on operational statistics are included at the end of this division. The program includes the entire routine of "Aerotriangulation: Image Coordinate Refinement"[18] (ending with line 173) as a preliminary phase to the three-photo analysis.

The list also includes numerous comment statements which serve to divide the program into distinct sections. These sections, also identified by serial-line numbers, serve as a basis for describing the program in 26 parts. It is convenient to refer to the serial numbers as "line numbers" in denoting parts of the program. Where the branching instructions IF and DO refer to statements in distant locations in the program, a notation such as "239: line 124" is added to specify that statement 239 occurs on line 124.

1. Input of Constants (lines 004 to 012).

The division on "Input Formats," described in pages 10 to 11, enumerates the various data that are the subject of five READ statements. The first two statements contain information that relates to all the photographs of the strip, whereas the last three statements refer to the geometric parameters of the camera that also are constant throughout the strip.

This is the first of eight sections which comprise the refinement of the observed-image coordinates before beginning the geometric-orientation solution. The refinement applies numerous systematic corrections to the observations, deriving the average value of several observations, film distortion, comparator calibration, symmetric radial lens distortion, asymmetric radial lens distortion, atmospheric refraction, and possibly also earth curvature.

2. Meaning Comparator Readings of Fiducial Marks (lines 019 to 080).

The program permits the comparator operator to repeat his observations for any image up to 10 times by merely leaving the point-identification number unchanged. A sequence check is made in order to ensure that the cards are in their proper order; if not, the program stops, prints an error message, and then goes to the next strip.

The average value of the several coordinate observations is determined for x and y, and the deviation of each observation from the mean is computed. The largest x-deviation is formed and is compared to a 25-micron limit. If two observations in any set exceed the limit, the program stops, prints an error message, and then goes to the next strip. If the x-coordinates pass the limit, then the y's are examined similarly, continuing the count of bad data from the x-analysis.

3. Correct x, y for Comparator Error by Using Matrix for Film Shrinkage and Orientation of Plate (lines 081 to 094).

This film distortion-compensation system corrects simultaneously for (1) x-screw, y-screw, and the skew of the ways of the comparator, and (2) film distortion, by comparing the observed coordinates of the fiducial marks with known values that already contain the comparator corrections, as shown in Equations 1 and 2 of Technical Bulletin No. 25.[19] This section computes the values of the coefficients in a set of observation equations where the unknowns are the coefficients of polynomial correction equations, used as constants throughout this photograph.

4. Formation and Solution of Normal Equations (lines 095 to 119).

These equations refer to the preceding section 3. Although a least-squares technique is not necessary and has no special significance, nevertheless, that routine is utilized because it is already programed. The least-squares routine is also discussed in Technical Bulletins Nos. 21 and 23.[20] [21] The same general solution is used in section 18 below, where the matrix is compressed; matrix compression is not required in the present case. The solution is executed in a portion of the same A-array storage area reserved for section 18.

As the x- and y-equations are identical except for the constant term, the solutions are facilitated.

5. Processing Nonfiducial Image Readings From Comparator (lines 120 to 129).

The routine of section 2 for fiducial marks is used again in this section to process the coordinates of photographic images. Section 5 sets up the routine for finding the average values of the multiple observations of the coordinates, and eliminates values that differ from the mean by more than 25 microns as in section 2.

6. Correction for Comparator Error, Film Shrinkage, and Orientation (lines 130 to 146).

The coefficients of the correction polynomials, derived in sections 3 and 4 and based on fiducial marks, are applied at this time to all the image coordinates on the photograph.

7. Correction for (so-called) Focal Plane Tilt (lines 147 to 154).

This correction to the image coordinates is for asymmetric radial lens distortion, which is distributed elliptically rather than circularly about the photograph, in addition to the symmetric radial lens distortion in succeeding section 8. This correction procedure (1) rotates the coordinate axes according to camera constants, (2) makes the correction to x and y, and (3) rotates back to the former coordinate axes. An equivalent correction also has been accomplished--with one less step--by avoiding the requirement for double rotation through the use of two direct quadratic polynomials. Because the present program functions well, efforts are not being expended to revise it.

8. Correction for Lens Distortion and Atmospheric Refraction (lines 155 to 173).

[18] Keller and Tewinkel, see footnote 3.

[19] Ibid.

[20] Harris, Tewinkel, and Whitten, p. 38, see footnote 1.

[21] Keller and Tewinkel, p. 6, see footnote 2.

As explained in Technical Bulletin No. 25,[22] the lens distortion consists of the symmetric-radial type which is depicted by the 151 constant values stored in the T-array. The program derives intermediate values by interpolating between the values specified at the even millimeters of radial distance.

Also, the atmospheric-refraction correction is based on the tables of Leijonhufvud,[23] incorporated in the two constants A(42, 1) and A(42, 2). Earth curvature can be taken into account as indicated in Technical Bulletin No. 25.[24]

This concludes the series of steps called image coordinate refinement. Repeated solutions of the following orientation steps do not involve sections 1 through 8.

Incorporated in section 8 are a few other details. If a block adjustment is to follow this strip adjustment, the refined-image coordinates are needed again. The values cannot remain in storage at this time because the array is to be filled with data pertaining to the next triplet. Consequently, the refined coordinates are punched out (line 167) according to whether a 1 or 0 exists in A(41, 5) as input on line 006.

Processing plates 2 and 3, as indicated on line 168, relates to whether the initial triplet is being processed or not, in which instance the data for these two photographs also must be processed like the first photograph. After the initial triplet, only the new data for the third photograph need processing.

9. Sorting Test (lines 174 to 205).

Preparations are made in this section to start the orientation solution. Feedback is provided in the value of NBAD and is generated on line 441. Section 9 realines the data for the next iteration.

10. Three-Photo Orientation (line 206).

The geometric solution of the three-photo orientation problem begins at this place and continues through section 20 (ending with line 566).

11. C-Array, Rows 1 Through 15 (lines 207 to 263).

The first 15 rows of the C-array contain elements that are common to all the images of a photograph. Except for the first row, these elements are all combinations of trigonometric functions, including the nine direction cosines of the three-dimensional rotation matrix and their partial derivatives with respect to the three fundamental angles. These C-array terms are identified and given in equations 14, 22, 23, and 24 of Technical Bulletin No. 21.[25] In the present program, the products of terms are formed explicitly rather than through matrix multiplication.

12. C-Array, Rows 16 Through 21, and E-Array (lines 264 to 285).

The remaining rows of the C-array consist of the scalar AB-matrix products, used later for forming the coefficients of table 1, previously discussed. These rows are computed for each image.

13. Intersection Routine (lines 285 to 305).

"Intersection" is a term that is used in this paper to indicate the approximate determination of the X-, Y-, Z-space coordinates of an object that corresponds to its images on two photographs. Intersection is obtained through the solution for the coordinates of the point of intersection of two lines in space by the simultaneous solution of the space equations for the lines associated with the two images. Equations 5 and 6, previously discussed, define the solution. The routine is given in this section and then repeated in section 22 (line 612) because it became difficult to recall the sequence.

14. Compute p-Constants (lines 306 to 326).

The formulas for the 14 coefficients of the terms in the observation equations are stated in table 1 and programed in this section, taking advantage of the formula similarities and of the special arrangement of the terms in the C-array. Consequently, p_{11} and p_{21} are the constant terms, and constitute residual parallaxes; $p_{12} \ldots p_{14}$, $p_{22} \ldots p_{24}$ are the coefficients of the three angular terms; and $p_{15} \ldots p_{17}, p_{25} \ldots p_{27}$ are the coefficients of the linear terms. The coefficients are stored momentarily in a portion of the A-array that is never used otherwise.

15. Compute S-, T-Constants for First Triplet (lines 327 to 339).

As explained previously in the division on "The Scheme of the System," the initial triplet differs from the succeeding ones by the manner in which "scale" is determined. In the initial phase, a value for the air base is adopted to fix the scale because no other criterion exists; later, the previously located positions of objects are used to find the scale. The orientation solution is accomplished by recognizing that ΔX-, ΔY-, ΔZ-corrections to the intersected-coordinate values can be "eliminated" in the initial case through modifications to some of the terms as shown in Equations 4, given previously, by the inclusion of ST-products. The formulas that express the modifications are listed as Equation 5.

16. Compute Contribution to Normal Equations (lines 340 to 378).

Equation 32 of Technical Bulletin No. 23[26] shows the formation of normal equations from observation equations. At any time in the procedure, only two observation equations are available; more equations are derived later, and none is saved. The contributions to the terms of the normal equations are computed and added to the values already in storage. This program for the

[22]Keller and Tewinkel, see footnote 3.

[23]On astronomic, photogrammetric and trigonometric refraction by Axel Leijonhufvud, Kungl. Boktryckeriet *P. A. Norstedt & Soner*, Stockholm, 1950.

[24]Keller and Tewinkel, p. 4, see footnote 3.

[25]Harris, Tewinkel, and Whitten, p. 9, see footnote 1.

[26]Keller and Tewinkel, p. 6, see footnote 2.

solution of normal equations is unusual in the sense the terms are "compressed", relative to their classic location; the program utilizes the system of cases described earlier (and determined in succeeding section 17) to indicate where the respective products are stored.

Lines 342 and 343 multiply the three coefficients of the angular terms by 10--as a "scaling" measure to cause these coefficients to have a size comparable to that of the linear terms. This is justified because the angular terms, which are in radians, have no fixed natural relationship to the linear terms, which are in meters. The application of the factor 10 places the linear and angular terms in a comparable capacity--relative to the effectiveness in eliminating parallax (p_{11}, p_{21}).

Lines 362 through 367 pertain to the three model coordinates, whereas lines 373 through 378 pertain to the six camera parameters. Lines 368 to 372 deal with ST-terms for Case 3.

17. Index Values for Different Cases (lines 379 to 478).

Values are assigned to the terms IGO, LROW, K, J, NDEV, LINE that are used as instruction signals for forming or not forming certain coefficients, and for knowing where to store the contributing products to the system of normal equations. The cases are described in the division on "The 'Case' Concept" and illustrated by table 2 and figure 2. It is noteworthy that Cases 8 to 14 correspond to Cases 1 to 7, respectively; the only difference lies in the fact that the latter set pertains only to the initial triplet, whereas the former pertains to all succeeding triplets. Case 3 is recognized in the preceding section 16 (lines 368 to 372) and in this section (lines 422 to 425) which also applies to Case 10.

Lines 427 to 477 analyze the residual-parallax values, finding the largest one and comparing it to the limit A(41, 5) as specified by the input indicated on line 006; count the number of excessive values; print appropriate error messages; and replace the questionable image coordinates with those of its companion pass point *on all photographs;* and then proceed or stop the computation.

18. Solution of Normal Equations (lines 479 to 543).

The basic system for the solution also was applied in section 4 preceding, and is described in Technical Bulletins Nos. 21 and 23.[27] [28] In the present instance, the storage array no longer has the classic triangular shape. Instead, the triangle is compressed as described in the division on "Matrix Compression," previously discussed and shown in figures 4 and 5, taking advantage of the large number of terms that are known always to be zeros. Consequently, the simplified instructions, used in section 4, are modified in this section in order to recognize the special locations of the various coefficients in the memory.

The "answers" (adjustments) eventually replace the constant terms in the first 48 rows of the last (16th) column of the A-array, in which the bottom 6 adjustments (reading upward) are ΔZ_0, ΔY_0, ΔX_0, ΔK, $\Delta\varphi$, $\Delta\omega$ for the 3rd photograph of the triplet, etc. The first 36 values are the ΔX-, ΔY-, ΔZ-adjustments to the 12 "free" pass points. Finally, on line 541, the angular adjustments are multiplied by 10 to restore them to the radian measure in order to counteract their arbitrary "scaling" in section 16.

19. Add Least-Squares Results to C- and E-Arrays (lines 544 to 555).

The adjustments resulting from the foregoing least-squares analysis are applied to their respective parameters. The 12 terms that apply to the camera are stored in the C-array and the 36 terms that pertain to the coordinates of the pass point objects are found in the E-array.

20. Test Magnitude of Corrections for Orientation Parameters (lines 556 to 566).

The procedure repeats the complete solution of each triplet until no adjustment to the three angular parameters of either "free" photograph exceeds 10^{-5} radian, or about 2 arc seconds. Each of the six parameters, stored as shown in lines 540 to 543 of section 18, is tested accordingly. In any event, the computation returns to line 212 to modify the elements of the orientation matrix. This section constitutes the final part of the orientation problem *per se* which began with section 10.

21. X-, Y-, Z-Output for Pass Points (lines 567 to 594).

If the test for excessive residuals in line 431 of section 17 is satisfactory, the output (app. 3) for the triplet is executed by the instructions in this section.

The output routines for the initial, intermediate, and final triplets all differ in certain respects. Line 571 instructs the computer to output the coordinates of those objects that are found across the center of the initial photograph, even though these points do not fall on three photographs. After the initial situation, line 573 alone applies to those objects that are found on three photographs. Finally, section 25, as will be shown, outputs the corresponding data pertaining to the objects that are found across the center of the last photograph in the strip, even though, as in the initial case, these images appear on only two photographs.

PUNCH statements are included in order to yield data for direct use as input for the next program. The reliability, or precision, values are computed at this time. For the pass point objects, the precision is the root-mean-square of all the residual x- and y-parallaxes involved, ordinarily six points, but to a lesser number for the leading and trailing ends of the initial and final triplets. Also, the rms-parallax for the

[27] Harris, Tewinkel, and Whitten, p. 38, see footnote 1.
[28] Keller and Tewinkel, p. 6, see footnote 2.

triplet is computed as a reliability indicator; it is composed of all the pass point parallaxes.

22. Compute X, Y, Z of Other Objects (lines 595 to 630).

Objects other than pass points are not utilized in the adjustment, but are computed through the use of the intersection routine, and based on the results of the general adjustment. Only those objects are considered that are found in the overlap of the first two photographs of the triplet; any others are considered, in turn, later. After the objects (if any) are identified, the intersection routine, although previously programed in line 277 of section 12, is repeated in its entirety. The solution will yield a y-parallax (or y-difference) but no x-parallax, and only on one photograph. The average Y-coordinate value is output together with the y-difference, which is, in a sense, a criterion of reliability.

23. Output of Residual Parallaxes for Pass Points in Triplet (lines 631 to 634).

The residual parallaxes of each pass point image are stored for any triplet in the R-array. Those images that are found on two photographs have a y-parallax value from each photograph; those images on all three photographs have both x- and y-parallaxes. All the values are printed to (1) assist in diagnosing trouble, and (2) serve as aids to the compiler employing the data because both companion images need not be used.

24. Proceed to New Triplet (lines 635 to 651).

The data in the B-, C-, and E-arrays are shifted into the appropriate storage area to prepare for the next photograph. The data pertaining to the second photograph are substituted for those of the first (erasing the first), and the data pertaining to the third photograph are placed into the area formerly occupied by the second. Most data for the third photograph remain also in their former locations, and are used as the first approximations for the new incoming photograph. Then, the coordinates of the fiducial marks of the new photograph are input; the new coefficients of the shrinkage polynomial are determined; and the image coordinates are input, are refined by the new coefficients, and finally a new strip is begun with the new photograph in the third position.

25. Output Data for Right Side of Last Triplet in Strip (lines 652 to 662).

The object data near the center of the last photograph would not be output otherwise, except through this special attention, because these data are held ordinarily until they can be analyzed from all three photographs. The coordinates are stored already; it is only a matter of printing them.

26. Format Statements (lines 663 to 685).

All format statements, discussed in the division on "Output Formats," are listed as the final section of the program.

Operational Statistics

The program has been operated only on the IBM-7030 (STRETCH) computer of the Naval Weapons Laboratory at Dahlgren, Virginia. Of the core memory, consisting of 48,000 words of 64-bit length (14 digits), the program used only 3,949 words. Compilation time for this Fortran IV source program was 26 seconds, and the average running time was 3.29 seconds per triplet. A strip containing 19 triplets (21 photographs) ran in 58.8 seconds.

In addition, the subsequent strip adjustment program, described in Technical Bulletin No. 23,[29] required 6 seconds to compute.

Based on a computer charge of $300 per hour, the total cost for computing the strip of 21 photographs for both programs was $5.50. Thus, the computer cost per photograph was about 23.7 cents for the three-photo analysis, plus about 2.5 cents per photograph for the strip adjustment. That low cost is attributed to the availability of a very large and fast computer at a relatively low hourly charge.

[29]Keller and Tewinkel, see footnote 2.

Appendixes

APPENDIX 1

SAMPLE INPUT DATA

Although this listing is comprised of actual data, some preliminary processing has been accomplished. Whereas real data have an appearance as shown in Aerotriangulation: Image Coordinate Refinement by M. Keller and G. C. Tewinkel, C. and G. S. Technical Bulletin No. 25, March 1965, p. 8, the multiple readings of the image coordinates have been averaged already, and only the mean values to tenths of microns are indicated in the following data. Ordinarily, the tenths column is always zero because the least count of the comparator is 1 micron. For some computers, the coordinates of images on the left side of the first photograph and on the right side of the last photograph, shown here as zeros, should instead be input as realistic dummy numbers.

```
  SHENANDOAH TEST  KELLER
  -0000592  -0025100          25    (refraction; rejection limit)
0004  +50555490+00  +86279440+00  -33170000-03   15229000+00  (asymmetric   S1
         1  +1060021  +1060069 ⎫                     lens distortion; f.l.)  S1
         2  +1059948  -1059988 ⎪                                             S1
         3  -1059941  -1059988 ⎬ (correct coordinates of fiducial marks)     S1
         4  -1060002  +1060042 ⎭                                             S1
-2500-2500-2500-2333-2500-2400-2333-2286-2188-2222-2250-2091-2083-2077-2036 S1 1
-2000-1969-1941-1944-1921-1905-1890-1868-1848-1825-1796-1762-1726-1696-1666 S1 2
-1633-1587-1544-1503-1465-1429-1394-1362-1332-1300-1263-1227-1193-1156-1118 S1 3
-1080-1041-1002-0963-0927-0890-0853-0815-0774-0731-0691-0652-0611-0569-0529 S1 4
-0488-0448-0403-0357-0313-0274-0235-0194-0154-0116-0079-0042-0007+0027+0062 S1 5
+0100+0134+0169+0201+0233+0265+0299+0332+0364+0395+0429+0463+0492+0517+0543 S1 6
+0566+0585+0600+0615+0630+0642+0654+0666+0673+0681+0687+0690+0693+0694+0694 S1 7
+0695+0692+0682+0671+0660+0648+0636+0622+0606+0591+0574+0553+0532+0508+0483 S1 8
+0458+0434+0407+0380+0348+0314+0278+0240+0203+0167+0129+0089+0038-0019-0082 S1 9
-0144-0217-0292-0380-0468-0609-0738-0880-1084-1271-1448-1610-1769-1939-2114 S110
-2267                                                                      S111
                                                 (symmetric radial
        53  (photo no.)                            lens distortion)
   5300001  02309868  02361430 ⎫
   5300002  02310290  00240392 ⎬ (observed coordinates of fiducial marks)
   5300003  00188934  00240124 ⎪
   5300004  00188870  02361220 ⎭                                            1
   5352310
   5352311  (no images used on ⎫
   5352320  initial side of    ⎪
   5352321  first photo)       ⎪
   5352330                    ⎪
   5352331                    ⎪
   5353310  01213123  00231547 ⎪
   5353311  01199953  00274997 ⎪
   5353320  01250307  02218183 ⎪
   5353321  01237867  02236403 ⎪
   5353330  01265310  01313247 ⎪
   5353331  01255730  01343237 ⎬ (observed coordinates
   5355310  02231770  00299073 ⎪  of photographic images)
   5355311  02198420  00337773 ⎪
   5355320  02229853  02138673 ⎪
   5355321  02267417  02133187 ⎪
   5355330  02218830  01240820 ⎪
   5355331  02224043  01222083 ⎪
   5354101  01774290  01066197 ⎪
   5354201  01658330  00992397 ⎪
   5354202  01645970  01944183 ⎪
   5354203  01855087  02239903 ⎪
   5354205  01739543  00172467 ⎭
                                                                           1
        55
   5500001  02309288  02357424
   5500002  02309338  00236306
   5500003  00187898  00236494
   5500004  00188236  02357630                                             1
   5553310  00198877  00343943
   5553311  00188930  00387327
   5553320  00282577  02324850
   5553321  00271153  02343140
   5553330  00282710  01420660
   5553331  00273103  01450860
   5555310  01220127  00383430
   5555311  01187883  00422687
   5555320  01258423  02217343
   5555321  01298290  02210250
   5555330  01231637  01321660
   5555331  01236017  01302743
```

```
5557310  02241847  00387483
5557311  02284073  00373753
5557320  02104020  02088053
5557321  02112143  02140973
5557330  02198563  01212363
5557331  02170817  01206787
5554101  00784237  01159917
5557101  02183183  01577917
5557102  02358563  00966450
5554201  00667913  01089507
5554202  00670677  02040287
5554203  00890463  02328890
                                                                    1
     57
5700001  02309572  02356906
5700002  02309884  00235836
5700003  00188570  00235650
5700004  00188572  02356724                                         1
5755310  00256753  00486843
5755311  00226017  00527927
5755320  00379990  02324980
5755321  00422060  02315200
5755330  00314993  01426540
5755331  00317413  01407763
5757310  01272540  00442243
5757311  01314370  00427117
5757320  01229827  02145467
5757321  01242133  02197903
5757330  01277153  01266003
5757331  01248363  01262103
5759310  02105637  00285683
5759311  02155877  00393170
5759320  02031743  02073900
5759321  02099637  02167090
5759330  02082627  01210943
5759331  02131430  01271083
5757101  01275590  01632273
5757102  01417577  01013040
5758201  01614490  00710493
5758202  01620843  01527557
5758203  01813303  02335897
                                                                    1
     59
5900001  02307944  02358074
5900002  02308330  00236912
5900003  00186918  00236694
5900004  00186838  02357882                                         1
5957310  00388290  00526048
5957311  00430173  00509563
5957320  00396103  02223670
5957321  00410937  02275183
5957330  00418770  01347767
5957331  00389113  01344577
5959310  01217060  00343270
5959311  01272087  00449507
5959320  01192577  02134693
5959321  01263763  02226283
5959330  01222590  01271180
5959331  01272870  01330230
5961310  02189330  00244887
5961311  02167247  00370447
5961320  02223263  02117197
```

5961321	02181670	02202770	
5961330	02172783	01187230	
5961331	02205843	01248803	
5957101	00421793	01712940	
5957102	00546077	01092253	
5959101	01443163	02423687	
5958201	00740400	00783740	
5958202	00771110	01599347	
5958203	00980797	02400547	
			1
61			
6100001	02308302	02354674	
6100002	02308588	00233782	
6100003	00187518	00233816	
6100004	00187476	02354626	1
6159310	00267593	00434733	
6159311	00325373	00540050	
6159320	00269022	02219004	
6159321	00341660	02309315	
6159330	00289518	01359463	
6159331	00339940	01417758	
6161310	01228563	00326458	
6161311	01209065	00452005	
6161320	01293828	02192790	
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        E N D   O F   S T R I P   I N P U T   D A T A
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APPENDIX 2

THE FORTRAN IV SOURCE PROGRAM

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T         SUBTYPE,DATA
B         JOB,K34-41B7 ANALYTIC AEROTRIANGULATION
*         *****     *****     *****     *****     *****     *****     ***
*         OPERATOR - THE RUNNING TIME SHOULD BE ABOUT 5  MINUTES        *
*         *****     *****     *****     *****     *****     *****     ***
B         TYPE,COMPILGO,FORTRAN,PM
T         SUBTYPE,FORTRAN,LMAP,LSTRAP
C           A N A L Y T I C    A E R O T R I A N G U L A T I O N
C      REFINEMENT OF IMAGE COORDINATES READ ON COMPARATOR
       DIMENSION A(50,16),T(151),B(50,9),C(21,9),E(18,3),R(56,2)
  350  READ 500
       PRINT 500                 (title card--project name and strip no.)
       READ 508,(A(42,J),J=1,2),A(41,1),A(41,5) (refraction; rejection limit)
       READ 501,N,(A(42,J),J=3,6)  (no. of marks; asym. dist.; focal length)
       NM1=N-1                     (N Minus 1)
       NP1=N+1                     (N Plus 1)
       NP2=N+2                     (N Plus 2)          (correct fiducial
       READ 502,(A(I+30,1),(A(I+30,J+1),J=N,NP1),ITEST,I=1,N)      coords.)
       READ 503,(T(I),I=1,151)   (symmetric radial lens distortion table)
       IBLOCK=1                              (test no. for initial triplet)
       NCOL=1
       NBAD=0                          (no. of residuals that exceed limit)
       DO 156 I=1,N                    (store correct coordinates
       A(43,I)=A(I+30,NP1)                                of fiducial marks)
  156  A(46,I)=A(I+30,NP2)
C        MEANING COMPARATOR READINGS OF FIDUCIALS
  248  ITRANS=1                (1 means fiducial mark; 2 means photo image)
       READ 502, IPLATE                              (no. of photo in process)
       IF (IPLATE)238,355,238     (355: line 653)(if 0, process images on
  238  LINE=31                                   right side of last triplet)
       I=31
  204  READ 502,(A(I,J),J=12,14),ITEST     (observed fiducial coordinates)
  241  GO TO (222,239),ITRANS                                (239: line 124)
  222  IF (A(31,12)-A(I,12))151,150,203                     (sequence check)
  203  PRINT 504                                            (error  message)
       GO TO 352                                             (352: line 649)
  150  IF (ITEST)202,202,199       (finding last of multiple observations)
  202  I=I+1
       GO TO 204                                             (204: line 025)
  199  I=I+1
  151  LROW = I-1
       K=LROW-30                       (K is no. of multiple observations)
       FK=K
       NDEV=1                                  (count of large deviations)
  219  IGO=1
       A(LINE,2) =0.                                       (initialization)
       A(LINE,3) =0.
       DO 205 I=31,LROW
       A(LINE,2) =A(LINE,2) +A(I,13)                       (sum of x-coords.)
  205  A(LINE,3) =A(LINE,3) +A(I,14)                       (sum of y-coords.)
       A(LINE,2) =A(LINE,2)/FK                                  (mean of x's)
       A(LINE,3) =A(LINE,3)/FK                                  (mean of y's)
  251  DO 208 I=31,LROW
  208  A(I,11)=ABS (A(I,13)-A(LINE,2))                (x-deviation from mean)
       IF(2-NDEV)206,206,209                                (209: line 056)
  206  A(L,11)=0.
       GO TO 209
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  207 DO 152 I=31,LROW                                                    051
  152 A(I,11)=ABS (A(I,14)-A(LINE,3))          (y-deviation from mean)    052
      IGO=2                                                               053
      IF(2-NDEV)153,153,209                                               054
  153 A(M,11)=0.                                                          055
  209 L=31                                  (finding largest deviation)   056
      J=31                                                                057
  214 J=J+1                                                               058
      IF(J-LROW)155,155,154                          (154: line 063)      059
  155 IF(A(L,11)-A(J,11))215,214,214                                      060
  215 L=J                                                                 061
      GO TO 214                        (214: line 058) (217: line 072;    062
  154 IF(A(L,11)-0.000025)217,217,216  test for  excessive deviation)     063
  216 IF(2-NDEV)203,203,218     (203: line 028)(only one is permitted)    064
  218 PRINT 505,IPLATE,A(31,12)                          (error message)    065
      A(L,13)=0.                        (delete the observations for     066
      A(L,14)=0.                                 the  excessive image)   067
      FK=FK-1.                                                            068
      NDEV=2                                        (count of excesses)   069
      M=L                                                                 070
      GO TO 219            (219: line 038)(end of  deviation analysis)    071
  217 GO TO (207,220),IGO                                (207: line 051)  072
  220 GO TO (198,240),ITRANS      (240: line 125)(fiducials or images)    073
  198 LINE=LINE+1                                        (221: line 083)  074
      IF(N+30-LINE)221,197,197          (accounting for all fiducials)    075
  197 A(31,12)=A(LROW+1,12)                (image no.  for next point)    076
      A(31,13)=A(LROW+1,13)                                (x-coordinate)  077
      A(31,14)=A(LROW+1,14)                                (y-coordinate)  078
      I=31                                                                079
      GO TO 241                                              (241: line 026)  080
C       CORRECT X,Y FOR COMPARATOR ERROR BY USING MATRIX FOR FILM         081
C        SHRINKAGE AND ORIENTATION OF PLATE                               082
  221 LROW=N+30                                                           083
      DO 223 I=31,LROW                                                    084
      A(I,NP1) =A(I,NP1) - A(I,2)                  (cor.  to obs. x of fiducial)085
      A(I,NP2) = A(I,NP2) - A(I,3)                 (cor.  to obs. y of fiducial)086
      A(I,1) =1.                                   (coefficients for      087
      A(I,4) =A(I,2) *A(I,3)                        1.                    088
      IF(LROW-34)223,223,224                        xy                    089
  224 A(I,5) =A(I,2) *A(I,2)                        4 or 8 fids.          090
      A(I,6) =A(I,3) *A(I,3)                        x^2                   091
      A(I,7) =A(I,4) *A(I,3)                        y^2                   092
      A(I,8) =A(I,5) *A(I,3)                        xy^2                  093
  223 CONTINUE                                      x^2y                  094
C       FORMATION AND SOLUTION OF NORMAL EQUATIONS                        095
      DO 225 I=1,N                                                        096
      DO 225 J=I,NP2                                                      097
      A(I,J)=0.                                                           098
      DO 225 K=1,N                                                        099
  225 A(I,J)=A(I,J)+A(K+30,I)*A(K+30,J)   (normal equation formation)     100
      DO 227 I=1,N                                  (forward solution)    101
      SQR=SQRT (A(I,I))                                                   102
      DO 228 J=I,NP2                                                      103
  228 A(I,J)=A(I,J)/SQR                                                   104
      IF(I-N)229,230,230                                     (230: line 110)  105
  229 IP1=I+1                                                             106
      DO 227 L=IP1,N                                                      107
      DO 227 J=L,NP2                                                      108
  227 A(L,J)=A(L,J)-A(I,L)*A(I,J)                                         109
  230 A(N,NP1)=A(N,NP1)/A(N,N)                           (back solution)  110
      A(N,NP2)=A(N,NP2)/A(N,N)                                            111
      DO 231 I=1,NM1                                                      112
      NMI=N-I                                                             113
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      NMIP1=NMI+1
      DO 232 J=NMIP1,N
      A(NMI,NP1)=A(NMI,NP1)-A(J,NP1)*A(NMI,J)
  232 A(NMI,NP2)=A(NMI,NP2)-A(J,NP2)*A(NMI,J)
      A(NMI,NP1)=A(NMI,NP1)/A(NMI,NMI)
  231 A(NMI,NP2)=A(NMI,NP2)/A(NMI,NMI)          (end of back solution)
C       PROCESSING NONFIDUCIAL IMAGE READINGS FROM COMPARATOR
  237 ITRANS=2
      NROW=0                    (row in B where mean x and y are stored)
      GO TO 238          (238: line 023)   (to read image coordinates)
  239 IF(A(31,12)-A(I,12))151,150,151 (151: line 034;(sequence check)
  240 NROW=NROW+1                        150: line 030)
      B(NROW,NCOL)=A(31,12)                                (image number)
      B(NROW,NCOL+1)=A(31,2)                              (data transfer)
      B(NROW,NCOL+2)=A(31,3)
      IF(ITEST)197,197,242      (197: line 076)  (test for last image)
C       CORRECTION FOR COMPARATOR ERROR, FILM SHRINKAGE AND ORIENTATION
  242 DO 243 I=1,NROW
      DO 243 K=NP1,NP2                              (K designates x or y)
      IF(N-4)244,244,245                              (4 or 8 fiducials)
  244 A(31,1)= A(1,K) +A(2,K)*B(I,NCOL+1) +A(3,K)*B(I,NCOL+2) +A(4,K)*
     1B(I,NCOL+1)*B(I,NCOL+2)      (Eq. 1, Tech. Bull. 25, 4 fiducials)
      GO TO 246
  245 A(31,1)= A(1,K) +A(2,K)*B(I,NCOL+1) +A(3,K)*B(I,NCOL+2) +A(4,K)*
     1B(I,NCOL+1)*B(I,NCOL+2) +A(5,K)*B(I,NCOL+1)**2 +A(6,K)*B(I,NCOL+2)
     2**2 +A(7,K)*B(I,NCOL+1)*B(I,NCOL+2)**2 +A(8,K)*B(I,NCOL+1)**2*B(I,
     3NCOL+2)                      (Eq. 2, Tech. Bull. 25, 8 fiducials)
  246 IF(K-NP1)261,261,262
  261 X=A(31,1)+B(I,NCOL+1)                        (correction applied)
      GO TO 243
  262 B(I,NCOL+2)=A(31,1)+B(I,NCOL+2)
      B(I,NCOL+1) = X
  243 CONTINUE
C       CORRECTION FOR FOCAL PLANE TILT          (asymmetric distortion)
  257 DO 247 I=1,NROW                                  (247: line 162)
      X=A(42,3)*B(I,NCOL+1) +A(42,4)*B(I,NCOL+2)                (rotation)
      Y=-A(42,4)*B(I,NCOL+1) +A(42,3)*B(I,NCOL+2)               (rotation)
      B(I,NCOL+1)=X+A(42,5)*X*X                              (correction)
      B(I,NCOL+2)=Y+A(42,5)*X*Y                              (correction)
      X=A(42,3) * B(I,NCOL+1) - A(42,4) * B(I,NCOL+2)          (counter)
      Y=A(42,4) * B(I,NCOL+1) + A(42,3) * B(I,NCOL+2)         (rotation)
C       CORRECTION FOR LENS DISTORTION AND ATMOSPHERIC REFRACTION
      FK=SQRT (X*X + Y*Y)                       (image radial distance)
      K=FK*1000.
      F=K
      D=1.+((1000.*FK-F)*(T(K+2)-T(K+1)) + T(K+1)) *.000001 +A(42,1) +
     1FK*FK*A(42,2)              (correction factor for lens and atm.)
      B(I,NCOL+1) = X * D                  (correction applied; final
  247 B(I,NCOL+2) = Y * D                          refined coordinates)
      B(50, NCOL) = NROW
      IF(A(41,5)-1.)259,146,259
  146 K=NCOL+2
      DO 148 I=1,NROW
  148 PUNCH 509,(B(I,J),J=NCOL,K)
C       PROCESSING PLATES 2 AND 3
  259 DO 157 I=1,N
      A(I+30,NP1) = A(43,I)                (fiducial coordinates for
  157 A(I+30,NP1+1)=A(46,I)                                  new photo)
      NCOL=NCOL+3
  163 IF(NCOL-7)248,248,260                            (248: line 020)
C       SORTING TEST                   (end of coordinate refinement;
  260 IF(NBAD)211,210,211 (210: line 190)     begin photo orientation)
```

```
  211 DO 329 I=1,6                          (putting companion data      176
      L=I/2                                    in place of (bad)         177
      J=B(I,7)/100000.                       coordinates guilty          178
      FK=J*100000                           of excessive parallax)       179
      FK=B(I,7)-FK                                                       180
      IF(R(55,1)-FK)213,212,213                                          181
  213 IF(R(56,1)-FK)329,212,329                   (329: line 189)        182
  212 IF(I-2*L)121,121,122                                               183
  121 DO 123 J=7,9                                                       184
  123 B(I,J)=B(I-1,J)                                                    185
      GO TO 329                                                          186
  122 DO 124 J=7,9                                                       187
  124 B(I,J)=B(I+1,J)                                                    188
  329 CONTINUE                                                           189
  210 DO 130 J=4,7,3                                                     190
      DO 130 K=1,12                                                      191
      I=B(K,J)/100000.                                                   192
      FK=I*100000                                                        193
      FK=B(K,J)-FK                                                       194
      I=B(K+6,J-3)/100000.                            (sorting test)     195
      D=I*100000                                                         196
      D=B(K+6,J-3)-D                                                     197
      IF(FK-D)131,130,131                                                198
  131 PRINT 506, B(K,J),B(K+6,J-3)                                       199
      GO TO 352                                       (352: line 649)    200
  130 CONTINUE                                                           201
      NBAD=0                                          (initialization)   202
   72 IEND=0                                                             203
      ITRANS=1                                                           204
      GO TO(164,324),IBLOCK                (164: line 208;  324: line 211) 205
C     THREE PHOTO ORIENTATION                                            206
C       C ARRAY ROWS 1 THROUGH 15                                        207
  164 DO 265 J=1,9                            (only for first triplet)   208
      C(1,J)=0.                                                          209
  265 C(2,J)=0.                                                          210
  324 DO 132 I=1,33                                                      211
      DO 132 J=1,16                                                      212
  132 A(I,J)=0.                                                          213
      DO 133 I=34,48                                  (clearing memory)  214
      K=I-33                                                             215
      DO 133 J=K,16                                                      216
  133 A(I,J)=0.                                                          217
      LROW=0                                                             218
      IF(IBLOCK-1)196,196,269                     (skip on first solution) 219
  196 GO TO (195,269),ITRANS                          (269: line 253)    220
  195 J=1                                                                221
      IGO=1                              (for first photo of first triplet) 222
```

```
264 JP2=J+2                                                          223
    DO 266 K=J,JP2                                                   224
266 C(3,K) =SQRT(1.-C(2,K)*C(2,K))                                   225
    C(4,J)=C(3,J+1)*C(3,JP2)                                         226
    C(5,J)=-C(3,J+1)*C(2,JP2)                                        227
    C(6,J)=C(2,J+1)                                                  228
    C(10,J)=-C(2,J+1)*C(3,JP2)                                       229
    C(11,J)=C(2,J+1)*C(2,JP2)                                        230
    C(12,J)=C(3,J+1)                                                 231
    C(10,J+1)=C(4,J)*C(2,J)                                          232
    C(11,J+1)=C(5,J)*C(2,J)                                          233
    C(12,J+1)=C(2,J)*C(2,J+1)                                        234
    C(10,JP2)=-C(4,J)*C(3,J)                                         235
    C(11,JP2)=-C(5,J)*C(3,J)                                         236
    C(12,JP2)=-C(3,J)*C(2,J+1)                                       237
    C(4,J+1)=C(3,J)*C(2,JP2)  + C(12,J+1)*C(3,JP2)                   238
    C(5,J+1)=C(3,J)*C(3,JP2)  - C(12,J+1)*C(2,JP2)                   239
    C(6,J+1)=-C(2,J)*C(3,J+1)                                        240
    C(4,JP2)=C(2,J)*C(2,JP2) + C(10,J)*C(3,J)                        241
    C(5,JP2)=C(2,J)*C(3,JP2) + C(11,J)*C(3,J)                        242
    C(6,JP2)=C(3,J)*C(3,J+1)                                         243
    DO 267 I=7,9                                                     244
    C(I,J)=0.                                                        245
    C(I,J+1)=-C(I-3,JP2)                                             246
267 C(I,JP2)=C(I-3,J+1)                                              247
    DO 268 I=J,JP2                                                   248
    C(13,I)=C(5,I)                                                   249
    C(14,I)=-C(4,I)                                                  250
268 C(15,I)=0.                                                       251
271 GO TO (269,263,272),IGO          (263: line 259;  272: line 265) 252
269 J=4                                                              253
    IGO=2                                  (for second photo of triplet) 254
    IF(IBLOCK-1)170,170,264                                          255
170 GO TO(331,264),ITRANS                (reset during initial triplet) 256
331 C(1,J)=B(17,2)                                                   257
    GO TO 264                                        (264: line 223) 258
263 J=7                                                              259
    IGO=3                                             (for third photo) 260
    GO TO(330,264),ITRANS                                            261
330 C(1,J)=B(17,5)+C(1,J-3)          (initialize X_o'' for next triplet) 262
    GO TO 264                                                        263
C       C ARRAY ROWS 16 THROUGH 21 AND E ARRAY        (the AB products 264
272 IGO=1                                   and model coord. list)   265
    NDEV=37                                                          266
    LINE=42                                                          267
    J=4                                                              268
    JP2=J+2                                                          269
    K=1                                  (count of image processed)  270
328 GO TO (94,289),IBLOCK                          (289: line 297)   271
 94 M=4                                  (Equations 4 and 5 herein) 272
    DO 334 L=18,20                                                   273
    M=M+3                                                            274
    DO 334 I=J,JP2                                                   275
334 C(L,I-3)=C(M,I)*B(K,5) +C(M+1,I)*B(K,6) +C(M+2,I)*(-A(42,6))     276
275 DO 274 I=4,6                 (begin intersection routine - Eq. 6) 277
274 C(16,I)=C(4,I)*B(K,5) + C(5,I)*B(K,6) + C(6,I)*(-A(42,6))  (x*",etc) 278
    IF (IGO-4)129,129,142                                            279
129 DO 277 I=1,3                                   (x*', y*', z*')   280
277 C(16,I)=C(4,I)*B(K+6,2) + C(5,I)*B(K+6,3) + C(6,I)*(-A(42,6))    281
    GO TO 278                                                        282
142 DO 143 I=7,9                                   (x*", y*", z*")   283
```

```
143 C(16,I)=C(4,I)*B(K-6,8) + C(5,I)*B(K-6,9) +C(6,I)*(-A(42,6))
    J=7
    JP2=J+2
278 A(40,3)=C(16,J-3)/C(16,J-1)                          (u3, Eq. 5)
    A(40,4)=C(16,J-2)/C(16,J-1)                                (u4)
    A(40,2)=C(16,J)-A(40,3)*C(16,JP2)                          (u2)
    A(40,1)=C(1,JP2)*C(16,J)-C(1,J)*C(16,JP2)+C(1,J-3)*C(16,JP2)-
   1C(1,J-1)*A(40,3)*C(16,JP2)                                 (u1)
    E(K,3)=A(40,1)/A(40,2)                                      (Z)
    E(K,2)=C(1,J-2)+A(40,4)*(E(K,3)-C(1,J-1))                   (Y)
    E(K,1)=C(1,J-3)+A(40,3)*(E(K,3)-C(1,J-1))                   (X)
233 J=4                                          (for Case 5 images)
300 JP2=J+2
289 C(17,J) = E(K,1)-C(1,J)
    C(17,J+1)=E(K,2)-C(1,J+1)                    [X-Xo; Y-Yo; Z-Zo] = B̄
    C(17,JP2)=E(K,3)-C(1,JP2)
    M=4
    DO 279 L=18,21                                        (AB̄ products)
    DO 279 I=J,JP2
    C(L,I)=C(M,J)*C(17,J) + C(M,J+1)*C(17,J+1) + C(M,JP2)*C(17,JP2)
279 M=M+1
254 GO TO (273,273,290,292,273,292),IGO  (290: line 390;  292: line 401)
C     COMPUTE P CONSTANTS        (coeff. of obs. equations--table 1)
273 NCOL=1
    DO 280 L=18,21
    A(44,NCOL)=(B(K,J+1)*C(L,JP2)-(-A(42,6))*C(L,J))/C(18,JP2)(p11...p14)
    A(45,NCOL)=(B(K,JP2)*C(L,JP2)-(-A(42,6))*C(L,J+1))/C(18,JP2)(p21...p24)
280 NCOL=NCOL+1
    DO 281 I=J,JP2
    A(44,NCOL)=(B(K,J+1)*C(6,I) - (-A(42,6))*C(4,I))/C(18,JP2)(p15...p17)
    A(45,NCOL)=(B(K,JP2)*C(6,I) - (-A(42,6))*C(5,I))/C(18,JP2)(p25...p27)
281 NCOL=NCOL+1
    IF(IEND)344,344,171  (if IEND = 1, compute residual parallax;
171 IRR=IRR+1                                          344: line 325)
    R(IRR,1)=B(K,J)
    R(IRR,2)=A(45,1)
    GO TO (137,172,172,172,295,297),IGO        (residual parallaxes;
172 IRR=IRR+1                                 137: line 380;  295: line 409;
    R(IRR,1)=B(K,J)                                      297: line 420)
    R(IRR,2)=A(44,1)
    GO TO (137,137,138,293),IGO          (138: line 392;  293: line 403)
344 GO TO (270,92),IBLOCK
270 IF (IGO-1)89,89,92                                   (92: line 334)
C     COMPUTE S,T CONSTANTS FOR FIRST TRIPLET. STORE -P11, -P21
 89 DO 326 I=44,45                                      (Equation  5)
326 A(I,8)=(1./A(40,2))*(A(I,5)*A(40,3)+A(I,6)*A(40,4)+A(I,7)) (S1, S2)
    M=2
    DO 327 L=18,20
    A(41,M)=C(17,J)*C(L,J-1) - C(17,JP2)*C(L,J-3)          (T2, T3, T4)
327 M=M+1
 92 A(49,16)=-A(44,1)                          (storage of p11, p21)
    A(50,16)=-A(45,1)
    DO 282 I=49,50    (clear area to store 2 observation equations)
    DO 282 M=1,15
282 A(I,M)=0.
    GO TO (134,134,287,139,134,139),IGO (287: line 351;  139: line 355)
C     COMPUTE CONTRIBUTION TO NORMAL EQUATIONS
```

```
134 DO 283 M=4,6                                                        341
    A(49,M)=A(44,M-2)*10.          (scale factor for coeff.             342
283 A(50,M)=A(45,M-2)*10.            of angular parameters)             343
    DO 284 M=7,9                                                        344
    A(49,M)=-A(44,M-2)                                                  345
284 A(50,M)=-A(45,M-2)                                                  346
    GO TO (285,286),IBLOCK          (ΔX_o'' = o for first               347
285 A(49,7)=0.                            triplet only)                 348
    A(50,7)=0.                                                          349
286 IF(IGO-1)88,88,287                     (88: line 368)               350
287 DO 288 M=1,3                (transfer ΔX, ΔY, ΔZ coeff.             351
    A(49,M)=A(44,M+4)                for compressed format)             352
288 A(50,M)=A(45,M+4)                                                   353
    GO TO 127                              (127: line 362)              354
139 DO 140 M=10,12                                                      355
    A(49,M)=A(44,M-8)*10.                                               356
140 A(50,M)=A(45,M-8)*10.                                               357
    DO 141 M=13,15                                                      358
    A(49,M)=-A(44,M-8)                                                  359
141 A(50,M)=-A(45,M-8)                                                  360
    GO TO 287                              (287: line 351)              361
127 DO 128 I=1,3                                                        362
    LROW=LROW+1                                                         363
    DO 128 M=I,16                              (contribution to         364
    A(LROW,M)=A(LROW,M) + A(49,I)*A(49,M)      normal equations)        365
128 A(LROW,M)=A(LROW,M) + A(50,I)*A(50,M)                               366
256 IF (IGO-3)125,138,125                (125: line 373;  138: line 392) 367
 88 GO TO (165,125),IBLOCK                                              368
165 DO 93 I=49,50                          (apply ST-terms              369
    A(I,9)=A(I,9) +A(I-5,8)*C(16,J)         only for Case 3)            370
    DO 93 M=4,6                                                         371
 93 A(I,M)=A(I,M) +A(I-5,8)*A(41,M-2)*10.                               372
125 DO 126 I=NDEV,LINE                                                  373
    L=I-33                                                              374
    DO 126 M=L,16                              (contribution to         375
    A(I,M)=A(I,M) + A(49,L)*A(49,M)             normal equations)       376
126 A(I,M)=A(I,M) + A(50,L)*A(50,M)                                     377
    GO TO (137,137,137,293,295,297),IGO        (293, 295, and 297: lines 378
C     INDEX VALUES FOR DIFFERENT CASES            403, 409, and 420)    379
137 K=K+1                                                               380
    IF(K-6)328,328,276                         (328: line 271)          381
276 IF(K-12)135,135,136                                                 382
135 IGO=2                                   (Cases 4 and 11, etc.)      383
    GO TO (275,289),ITRANS          (275: line 277;  289: line 297)     384
136 LROW=0                                                              385
    IGO=3                                                               386
    K=7                                     (Cases 2 and 9, etc.)       387
    J=1                                                                 388
    GO TO 300                                  (300: line 296)          389
290 K=K+6                                                               390
    GO TO 273                                                           391
138 K=K-5                                                               392
    IF(K-12)289,289,291                        (289: line 297)          393
291 IGO=4                                                               394
    LROW=0                                                              395
    K=7                                                                 396
    J=7                                                                 397
    NDEV=43                                 (Cases 6 and 13, etc.)      398
    LINE=48                                                             399
    GO TO 300                                  (300: line 296)          400
292 K=K-6                                                               401
    GO TO 273                                  (273: line 307)          402
```

photo 2

photo 3

```
293 K=K+7                                                          403
    IF(K-12)289,289,294                          (289: line 297)   404
294 IGO=5                                                          405
    NDEV=37                                                        406
    LINE=42                                  (Cases 5 and 12, etc.) 407
    GO TO(275,233),ITRANS                (275: line 277;  233: line 295) 408
295 K=K+1                                                          409
    GO TO (345,346),ITRANS                                         410
345 IF(K-18)275,275,296                                            411
346 IF(K-18)289,289,296                          (289: line 297)   412
296 IGO=6                                                          413
    LROW=18                                                        414
    J=7                                                            415
    K=13                                     (Cases 7 and 14, etc.) 416
    NDEV=43                                                        417
    LINE=48                                                        418
    GO TO 300                                                      419
297 K=K+7                                                          420
    IF(K-18)289,289,194                          (289: line 297)   421
194 IF (IEND)298,298,173  (to least squares or residuals)(298: line 480) 422
173 IF(IBLOCK-1)192,192,234                (analyze for residuals  423
192 I=1                                          in proper cases)  424
    GO TO 235                                                      425
234 I=7                                                            426
235 M=I                                              (finding largest 427
177 M=M+1                                          absolute residual) 428
    IF(M-54)174,174,175                                            429
174 IF(ABS(R(I,2)) - ABS(R(M,2)))176,177,177         (177: line 428) 430
176 I=M                                                            431
    GO TO 177                                        (168: line 568) 432
175 IF(ABS(R(I,2))-A(41,1))168,168,178 (test: 168 if ok; 178 if bad) 433
178 IF(I-6)339,339,340 (339: line 440)(identification of bad residual) 434
340 IF(I-42)341,341,339                                            435
341 L=I/2                                                          436
    IF (I-2*L)342,342,339                                          437
342 PRINT 514,R(I,1),R(I,2)                          (error message) 438
    GO TO 343                                                      439
339 PRINT 507,R(I,1),R(I,2)                          (error message) 440
343 NBAD=NBAD+1                          (count of excessive residuals) 441
    GO TO (182,183,184),NBAD             (182: line 451;  184: line 449) 442
183 J=R(I,1)/100000.                                               443
    FK=J*100000                                                    444
    FK=R(I,1)-FK                                                   445
    IF(ABS(R(55,1) - FK) - 1.)185,185,182            (both images bad?) 446
185 PRINT 511                                            (error message) 447
    GO TO 352                                            (352: line 649) 448
184 PRINT 513                                            (error message) 449
    GO TO 352                                                  (bypass) 450
182 J=R(I,1)/100000.                                               451
    FK=J*100000                                                    452
    R(55,1)=R(I,1)-FK                                              453
    GO TO (253,236),NBAD                                           454
253 R(56,1)=R(55,1)                                                455
```

```
  236 DO 187 I=1,18                                  (187: line 477)
      L=I/2
      M=1
  186 NCOL=M+2
      J=B(I,M)/100000.                   (search storage for the bad
      FK=J*100000                          data and replace it with
      FK=B(I,M)-FK                         companion data)
      IF(M-4)338,188,189                   (188: line 467;  189: line 470)
  338 IF(R(55,1)-FK)190,193,190                     (193: line 471)
  190 M=4
      GO TO 186                                     (186: line 459)
  188 IF(R(55,1)-FK)249,193,249
  249 M=7
      GO TO 186
  189 IF(R(55,1)-FK)187,193,187                     (187: line 477)
  193 IF(I-2*L)158,158,159                          (159: line 475)
  158 DO 336 J=M,NCOL
  336 B(I,J)=B(I-1,J)
      GO TO 187
  159 DO 337 J=M,NCOL
  337 B(I,J)=B(I+1,J)
  187 CONTINUE
      GO TO 72                                       (72: line 203)
C       SOLUTION OF NORMAL EQUATIONS
  298 LINE=1                         (Gauss elimination with square
  147 NROW=0                          root technique as shown in
      DO 310 M=1,12                   Appendix 12, Tech. Bull. 21,
      LROW=LINE+2                     but applied here to the
      DO 309 I=1,3                    "compressed" format; same
      NROW=NROW+1                     solution as applied on line 095.)
      SQR=SQRT(A(NROW,I))
      DO 308 J=I,16
  308 A(NROW,J)=A(NROW,J)/SQR
      IF (I-3)307,310,307
  307 K=NROW+1
      ME=I
      DO 309 L=K,LROW
      ME=ME+1
      DO 309 J=ME,16
  309 A(L,J)=A(L,J)-A(NROW,ME)*A(NROW,J)
  310 LINE=LINE+3
      K=3
      DO 301 L=37,48
      K=K+1
      DO 301 I=1,36
      DO 301 J=K,16
  301 A(L,J)=A(L,J)-A(I,K)*A(I,J)
  149 DO 302 I=37,48
      K=I-33
      IF(A(I,K))299,302,299                     (302: line 515)
  299 SQR=SQRT(A(I,K))
      DO 303 J=K,16
  303 A(I,J)=A(I,J)/SQR
      IF (I-48)304,306,306                      (306: line 516)
  304 IP1=I+1
      DO 335 L=IP1,48
      K=K+1
      DO 335 J=K,16
  335 A(L,J)=A(L,J)-A(I,K)*A(I,J)
  302 CONTINUE                          (end of forward solution)
```

```
  306 A(48,16)=A(48,16)/A(48,15)                    (begin back solution)
      DO 311 I=1,11
      NMI=48-I
      K=NMI-32
      DO 305 J=K,15
      IF(A(NMI,K-1))305,311,305
  305 A(NMI,16)=A(NMI,16) -A(J+33,16)*A(NMI,J)
      A(NMI,16)=A(NMI,16)/A(NMI,K-1)                 (camera parameters)
  311 CONTINUE
      LROW=11
  313 DO 312 I=1,3
      L=I+LROW
      K=4-I
      NROW=48-L
      DO 315 J=4,15
  315 A(NROW,16)=A(NROW,16)-A(J+33,16)*A(NROW,J)
      IF (I-2)312,316,317
  316 A(NROW,16)=A(NROW,16)-A(NROW+1,16)*A(NROW,3)
      GO TO 312
  317 A(NROW,16)=A(NROW,16)-A(NROW+2,16)*A(NROW,3)
      A(NROW,16)=A(NROW,16)-A(NROW+1,16)*A(NROW,2)
  312 A(NROW,16)=A(NROW,16)/A(NROW,K)              (object coordinates)
      LROW=L
      IF (LROW-44)313,313,314                           (313: line 526)
  314 DO 144 I=37,39
  144 A(I,16)=A(I,16)*10.                  (rescaling factor for angular
      DO 145 I=43,45                          parameters)
  145 A(I,16)=A(I,16)*10.                        (end of back solution)
C     ADD LEAST SQUARES RESULTS TO C AND E ARRAYS
      DO 321 J=4,6
      C(2,J)=C(2,J)+A(J+33,16)                 (application of 48 computed
  321 C(1,J)=C(1,J)+A(J+36,16)                    adjustments)
      DO 322 J=7,9
      C(2,J)=C(2,J)+A(J+36,16)
  322 C(1,J)=C(1,J)+A(J+39,16)
      M=1
      DO 325 I=7,18
      DO 325 J=1,3
      E(I,J)=E(I,J)+A(M,16)
  325 M=M+1
C       TEST MAGNITUDE OF CORRECTIONS FOR ORIENTATION PARAMETERS
      DO 318 I=37,39
      IF(ABS(A(I,16))-.00001)318,318,319       (test of angular corrections:
  318 CONTINUE                                   must all be less than
      DO 320 I=43,45                             .00001 radian--about 2
      IF(ABS(A(I,16))-.00001)320,320,319         arc seconds)
  320 CONTINUE
      IEND=1
      IRR=0
  319 ITRANS=2
      GO TO 324                                   (line 211 for repeat)
C       X Y Z OUTPUT FOR PASS POINTS                (object coordinates)
                                                       (from line 433)
  168 PRINT 512
      L=0                              (signal for finding reliabilities)
      GO TO(323,332),IBLOCK
  323 K=1                                          (for first triplet)
      GO TO 160
  332 K=7                                     (for subsequent triplets)
  160 M=12
      DO 161 I=K,M                                     (161: line 589)
      J=B(I,4)/100000.
      FK=J*1C0000
```

```
      FK=B(I,4)-FK
      IF(I-6)179,179,180
  180 NCOL=I+L
      X =  SQRT ((R(NCOL,2)**2+R(NCOL+1,2)**2+R(NCOL+12,2)**2+R(NCOL+13,
     12)**2+R(NCOL+24,2)**2+R(NCOL+25,2)**2)/6.) (object reliability)
      PRINT 509,FK,(E(I,J),J=1,3),X
      PUNCH 509,FK,(E(I,J),J=1,3),X
      L=L+1                                        (object no., X, Y, Z, and
      GO TO 161                                      sigma reliability)
  179 PRINT 509,FK,(E(I,J),J=1,3),R(I,2)
      PUNCH 509,FK,(E(I,J),J=1,3),R(I,2)
  161 CONTINUE
      R(55,2)=0.                                     (triplet reliability,
      DO 181 I=1,54                                rms. residual parallaxes)
  181 R(55,2)=R(55,2)+R(I,2)**2
      R(55,2)=SQRT(R(55,2)/42.)
      PRINT 510,R(55,2)
C       COMPUTE X Y Z OF OTHER OBJECTS           (images, not used in adjust-
  357 PRINT 515                                     ment, lying in photos 1 and 2)
      L=B(50,4)
      M=B(50,1)
      IF(L-18)333,360,333
  333 IF(M-18)226,360,226
  226 DO 347 K=19,M
      J=B(K,1)/100000.                             (search for other objects)
      FK=J*100000
      FK=B(K,1)-FK
      DO 349 NCOL=19,L
      J=B(NCOL,4)/100000.
      D=J*100000
      D=B(NCOL,4)-D
      IF(FK-D)349,351,349
  349 CONTINUE                                 (begin intersection routine: Eq. 6;
      GO TO 347    (347: line 629) x*', y*', z*' ;  see also line 277)
  351 DO 348 I=1,3
  348 C(16,I)=C(4,I)*B(K,2) + C(5,I)*B(K,3) + C(6,I)*(-A(42,6))
      DO 255 I=4,6                                          (x*", y*", z*")
  255 C(16,I)=C(4,I)*B(NCOL,5)+C(5,I)*B(NCOL,6)+C(6,I)*(-A(42,6))
      A(40,3)=C(16,1)/C(16,3)                                   (u3)
      A(40,4)=C(16,2)/C(16,3)                                   (u4)
      A(40,2)=C(16,4)-A(40,3)*C(16,6)                           (u2)
      A(40,1)=C(1,6)*C(16,4)-C(1,4)*C(16,6)+C(1,1)*C(16,6)-C(1,3)*A(40,3
     1)*C(16,6)                                                 (u1)
      E(1,3)=A(40,1)/A(40,2)                                     (Z)
      E(1,2)=C(1,2)+A(40,4)*(E(1,3)-C(1,3))                      (Y')
      E(1,1)=C(1,1)+A(40,3)*(E(1,3)-C(1,3))                      (X')
      E(2,2)=C(1,5)+(C(16,5)/C(16,6))*(E(1,3)-C(1,6))            (Y")
      Y=E(2,2)-E(1,2)                                  (Y-difference)
      E(1,2)=(E(1,2)+E(2,2))/2.                        (mean Y)
      PUNCH 509,FK,(E(1,J),J=1,3),Y                    (object no., X,Y,Z,Y-diff)
      PRINT 509,FK,(E(1,J),J=1,3),Y
  347 CONTINUE                                     (end of intersection routine)
  360 IF (IPLATE)358,359,358 (359: line 661)          (359 = go to next strip)
C       OUTPUT OF RESIDUAL PARALLAXES FOR PASS POINTS IN TRIPLET
  358 PRINT 517
      DO 258 I=1,54
  258 PRINT 509,R(I,1),R(I,2)                 (image no. and residual parallax)
C       PROCEED TO NEW TRIPLET
      PRINT 516
      IBLOCK=2                                     (not first triplet hereafter)
      DO 169 I=1,6                                      (shift data in E-array
      DO 169 J=1,3                                   to accommodate  new photo
```

```
169 E(I,J)=E(I+6,J)                                    in next triplet)
    DO 162 I=1,50                                  (shift data in B-array)
    DO 162 J=1,6
162 B(I,J)=B(I,J+3)
    DO 166 I=1,15                                (shift data in C-array)
    DO 166 J=1,6
166 C(I,J)=C(I,J+3)
    NCOL=4
    GO TO 259        (259: line 169)(to refine coords. on new photo)
352 READ 518, I10, I80 (from lines 029, 448, or 450)
    IF(I10)352,353,352
353 IF(I80)352,350,352                              (350: line 004)
C     OUTPUT  DATA FOR RIGHT SIDE OF LAST TRIPLET IN STRIP
355 PRINT 512            (these require special output instructions;
    DO 356 I=13,18                                   from line 022)
    J=B(I,1)/100000.
    FK=J*100000
    FK=B(I,1)-FK
    PRINT 509,FK,(E(I,J),J=1,3),R(I+30,2)
356 PUNCH 509,FK,(E(I,J),J=1,3),R(I+30,2)
    GO TO 357                                       (357: line 596)
359 PRINT 519                                       (from line 630)
    GO TO 350                                       (350: line 004)
500 FORMAT(55H
501 FORMAT(1X,I3,4(2X,E12.8))                     (format statements)
502 FORMAT(3X,I7,2F10.7,49X,I1)
503 FORMAT(15F5.1)
504 FORMAT(78H MEASURED FIDUCIAL MARK CARDS NOT IN SEQUENCE OR 2 BAD
   1READINGS ON POINT-STOP)
505 FORMAT(38H DEV FROM MEAN OVER 25 MICRONS. PLATE I7, 7H POINT I7)
506 FORMAT(33H SORTING ERROR PREVENTS MATCHING I7, 5H AND I7, 5H-STOP)
507 FORMAT(/15H YPARALLAX FOR I7,4H IS E14.8, 18H AND EXCEEDS LIMIT)
508 FORMAT(2F10.7,F10.6,1X,I1)
509 FORMAT(3X,I7,4(2X,E14.8))
510 FORMAT(29H RMS PARALLAX FOR TRIPLET IS E14.8/)
511 FORMAT(52H  TWO BAD RESIDUAL PARALLAXES IN SAME LOCATION. STOP)
512 FORMAT(/71H    PASS PT        X                Y                Z
   1        PRECISION/)
513 FORMAT(53H  THREE BAD RESIDUAL PARALLAXES IN SAME TRIPLET. STOP)
514 FORMAT(/15H XPARALLAX FOR I7,4H IS E14.8, 18H AND EXCEEDS LIMIT)
515 FORMAT(/71H     OBJECT        X                Y                Z
   1        PRECISION/)
516 FORMAT(/27H       N E W   T R I P L E T/)
517 FORMAT(/33H    IMAGE   RESIDUAL X,Y PARALLAX/)
518 FORMAT(I10,69X,I1)
519 FORMAT(/49H ** STRIP ANALYTIC AEROTRIANGULATION COMPLETED **/)
    END
```

APPENDIX 3

SAMPLE OUTPUT DATA

```
BEGIN EXECUTION
 SHENANDOAH TEST  KELLER
```

PASS PT	X	Y	Z	PRECISION
53310	-.35789644E-02	-.10490047E-00	-.14948307E-00	.10413823E-05
53311	-.48801101E-02	-.10083944E-00	-.14978282E-00	-.62021577E-05
53320	.90533380E-04	.89242252E-01	-.14821813E-00	.84007340E-05
53321	-.11199702E-02	.91063773E-01	-.14829780E-00	-.14343610E-04
53330	.15548733E-02	.12268798E-02	-.14974039E-00	.82699248E-05
53331	.61354081E-03	.41696881E-02	-.14960564E-00	.23287359E-05
55310	.96735567E-01	-.98688794E-01	-.15012582E-00	.61239655E-05
55311	.93436697E-01	-.94862324E-01	-.15009049E-00	.20176051E-05
55320	.95489451E-01	.81612377E-01	-.14841302E-00	.74968997E-05
55321	.99402348E-01	.81265535E-01	-.14879252E-00	.39892454E-05
55330	.95289934E-01	-.59084449E-02	-.14980184E-00	.34135948E-05
55331	.95747967E-01	-.77456911E-02	-.14969729E-00	.14479341E-04

RMS PARALLAX FOR TRIPLET IS .89992409E-05

OBJECT	X	Y	Z	PRECISION
54101	.51611306E-01	-.23083324E-01	-.14988473E-00	-.12225755E-04
54201	.40258777E-01	-.30378924E-01	-.15008589E-00	-.76085411E-05
54202	.38606402E-01	.62654600E-01	-.14834651E-00	.35027877E-04
54203	.59152753E-01	.91726891E-01	-.14880343E-00	.35890879E-04

IMAGE	RESIDUAL X,Y PARALLAX
5553310	.10413823E-05
5553311	-.62021577E-05
5553320	.84007340E-05
5553321	-.14343610E-04
5553330	.82699248E-05
5553331	.23287359E-05
5555310	.93270483E-05
5555310	-.79411012E-05
5555311	-.15809175E-05
5555311	-.31644825E-05
5555320	.84127342E-05
5555320	-.76799113E-05
5555321	.79581674E-06
5555321	-.11678143E-05
5555330	-.39770597E-06
5555330	-.31462637E-05
5555331	-.17238939E-04
5555331	.23172118E-04
5355310	-.49298034E-05
5355310	.37480818E-05
5355311	-.85794222E-06
5355311	.14108645E-05
5355320	-.12510351E-04
5355320	.31850189E-05
5355321	.64212468E-05
5355321	.94293370E-06
5355330	.54766433E-05
5355330	.18127576E-05
5355331	.59052563E-05
5355331	-.11193853E-04
5755310	-.44816428E-05
5755310	.40652920E-05
5755311	.23812216E-05
5755311	.18746502E-05
5755320	.39376063E-05
5755320	.50306994E-05
5755321	-.71570671E-05
5755321	-.37711037E-06
5755330	-.50772705E-05
5755330	.89456484E-06
5755331	.11564869E-04
5755331	-.11395579E-04
5557310	.14151217E-04
5557311	-.15195757E-04
5557320	.36375953E-05
5557321	-.56849126E-05
5557330	.49524667E-05
5557331	-.69692248E-06
5757310	-.14133189E-04
5757311	.15179651E-04
5757320	-.36169403E-05
5757321	.56521846E-05
5757330	-.49361861E-05
5757331	.69453307E-06

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
57310	.19685858E-00	-.94761097E-01	-.14879012E-00	.94427729E-05
57311	.20109013E-00	-.96000876E-01	-.14887045E-00	.10182143E-04
57320	.17916543E-00	.72024436E-01	-.14968916E-00	.31420015E-05
57321	.17994485E-00	.77393830E-01	-.14991328E-00	.37188630E-05
57330	.19079637E-00	-.14023073E-01	-.14949546E-00	.34787204E-05
57331	.18799377E-00	-.14639882E-01	-.14935495E-00	.31108058E-05

RMS PARALLAX FOR TRIPLET IS .67355076E-05

OBJECT	X	Y	Z	PRECISION
57101	.18772743E-00	.21748908E-01	-.14860573E-00	-.73609661E-05
57102	.20649986E-00	-.37618655E-01	-.14848957E-00	-.28685370E-04

IMAGE	RESIDUAL X,Y PARALLAX
5755310	-.49340023E-05
5755311	.19932285E-05
5755320	.31316965E-05
5755321	-.78889442E-05
5755330	-.49433705E-05
5755331	.11708137E-04
5757310	-.10047758E-04
5757310	-.26322978E-05
5757311	.10318781E-04
5757311	-.31079709E-05
5757320	-.50340647E-05
5757320	-.33908046E-05
5757321	.72248485E-05
5757321	.13705137E-05
5757330	-.65944408E-05
5757330	.21917562E-05
5757331	.20014523E-05
5757331	.54928892E-05
5557310	.18709553E-04
5557310	.17102155E-05
5557311	-.19995641E-04
5557311	.10359686E-05
5557320	.12184548E-05
5557320	.15216017E-05
5557321	-.45752607E-05
5557321	-.58095674E-06
5557330	.29939572E-05
5557330	-.11843809E-05
5557331	.68086586E-06
5557331	-.25838716E-05
5957310	-.86065690E-05
5957310	-.25318338E-06
5957311	.96855153E-05
5957311	.33483454E-05
5957320	.38735553E-05
5957320	.18945561E-05
5957321	-.26986835E-05
5957321	-.59118145E-06
5957330	.35773056E-05
5957330	-.10746522E-05
5957331	-.27503211E-05
5957331	-.30299831E-05
5759310	.26388754E-05
5759311	-.90378364E-06
5759320	.76503545E-05
5759321	-.49113866E-05
5759330	.20869778E-05
5759331	-.34799021E-05
5959310	-.26201979E-05
5959311	.89759505E-06
5959320	-.76519014E-05
5959321	.49123909E-05
5959330	-.20798755E-05
5959331	.34680138E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
59310	.27988529E-00	-.10369292E-00	-.14831305E-00	.16772242E-05
59311	.28416134E-00	-.92901768E-01	-.14859103E-00	.19202635E-05
59320	.25862512E-00	.71456399E-01	-.14916230E-00	.50830674E-05
59321	.26464685E-00	.81279635E-01	-.14929011E-00	.37816085E-05
59330	.27067878E-00	-.13053199E-01	-.14923874E-00	.28382214E-05
59331	.27499725E-00	-.67276654E-02	-.14918678E-00	.10808649E-05

RMS PARALLAX FOR TRIPLET IS .39151794E-05

OBJECT	X	Y	Z	PRECISION
57101	.18772741E-00	.21747172E-01	-.14860265E-00	.52423619E-05
57102	.20649200E-00	-.37620181E-01	-.14843111E-00	.47788144E-05
58201	.22844571E-00	-.66054557E-01	-.14932824E-00	.94162065E-05
58202	.22265536E-00	.14521583E-01	-.14989373E-00	.42568371E-05
58203	.23499474E-00	.95385311E-01	-.14925019E-00	-.15190122E-05

IMAGE	RESIDUAL X,Y PARALLAX
5957310	-.66337194E-05
5957311	.11651929E-04
5957320	.56880966E-05
5957321	-.59788407E-06
5957330	.28382516E-05
5957331	-.34098048E-05
5959310	-.14019464E-05
5959310	.25723960E-06
5959311	.12165082E-06
5959311	.37311857E-05
5959320	-.65706620E-05
5959320	-.27766165E-05
5959321	.40499978E-05
5959321	-.47400888E-05
5959330	-.30093013E-05
5959330	.29631731E-05
5959331	.20718161E-05
5959331	.37839977E-07
5759310	.33255888E-05
5759310	.17119712E-07
5759311	-.85915335E-06
5759311	-.19972040E-05
5759320	.95594355E-05
5759320	.18079109E-05
5759321	-.56634701E-05
5759321	.22506588E-05
5759330	.47420102E-05
5759330	-.13616981E-05
5759331	-.15657868E-05
5759331	-.28979830E-07
6159310	-.19042097E-05
6159310	-.40126386E-06
6159311	.70367039E-06
6159311	-.17221511E-05
6159320	-.29904761E-05
6159320	.74023531E-06
6159321	.16608681E-05
6159321	.26520959E-05
6159330	-.17461674E-05
6159330	-.17625927E-05
6159331	-.51232272E-06
6159331	.27514827E-07
5961310	-.20490990E-05
5961311	-.21147399E-05
5961320	-.47343562E-05
5961321	.81113957E-06
5961330	.10321889E-05
5961331	.23113964E-05
6161310	.20465530E-05
6161311	.21128308E-05
6161320	.47508021E-05
6161321	-.81412177E-06
6161330	-.10333605E-05
6161331	-.23142706E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
61310	.37499200E-00	-.10234928E-00	-.14703934E-00	.13851582E-05
61311	.37168721E-00	-.90533163E-01	-.14723326E-00	.20101664E-05
61320	.35998069E-00	.80540364E-01	-.14894973E-00	.44377066E-05
61321	.35500071E-00	.88501422E-01	-.14896807E-00	.33906290E-05
61330	.36420005E-00	-.11268382E-01	-.14796910E-00	.10855465E-05
61331	.36695106E-00	-.49132698E-02	-.14823463E-00	.24783106E-05

RMS PARALLAX FOR TRIPLET IS .26998418E-05

OBJECT	X	Y	Z	PRECISION

(no other objects)

IMAGE	RESIDUAL X,Y PARALLAX
6159310	-.22814537E-05
6159311	.45556840E-06
6159320	-.31206877E-05
6159321	.14505689E-05
6159330	-.16516194E-05
6159331	-.40129606E-06
6161310	.18144683E-05
6161310	.88752726E-06
6161311	.28404313E-05
6161311	-.26737437E-05
6161320	.16441165E-05
6161320	.53092901E-05
6161321	.12321616E-05
6161321	-.56238784E-05
6161330	-.17611291E-05
6161330	-.45221873E-06
6161331	-.98790367E-06
6161331	.30575698E-05
5961310	-.25467676E-05
5961310	-.57916759E-06
5961311	-.22262058E-05
5961311	.12659346E-05
5961320	-.68048561E-05
5961320	-.31404690E-05
5961321	.24922473E-05
5961321	.30557538E-05
5961330	-.13384959E-06
5961330	.13199652E-06
5961331	.37198352E-05
5961331	-.12415160E-05
6361310	.73537625E-06
6361310	-.26408571E-06
6361311	-.63461239E-06
6361311	.14374782E-05
6361320	.51901400E-05
6361320	-.20399979E-05
6361321	-.37481940E-05
6361321	.24968130E-05
6361330	.18973411E-05
6361330	.35937154E-06
6361331	-.27331394E-05
6361331	-.19180376E-05
6163310	.28766038E-06
6163311	.25167857E-06
6163320	-.13631598E-05
6163321	.24244557E-05
6163330	-.12646255E-05
6163331	.38814770E-06
6363310	-.28868785E-06
6363311	-.25271660E-06
6363320	.13559260E-05
6363321	-.24117026E-05
6363330	.12641649E-05
6363331	-.38807849E-06

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
63310	.47073677E-00	-.90066817E-01	-.14825424E-00	.46898144E-05
63311	.46806829E-00	-.93370103E-01	-.14784118E-00	.29089646E-05
63320	.44598274E-00	.81673586E-01	-.14882245E-00	.27839094E-05
63321	.44247019E-00	.81611415E-01	-.14890571E-00	.38513176E-05
63330	.45637547E-00	-.76967909E-02	-.14860223E-00	.11629019E-05
63331	.45457533E-00	-.10653795E-01	-.14894084E-00	.45590154E-05

RMS PARALLAX FOR TRIPLET IS .35873358E-05

OBJECT	X	Y	Z	PRECISION
61101	.36080768E-00	.42430300E-01	-.14656918E-00	.12208277E-04

IMAGE	RESIDUAL X,Y PARALLAX
6361310	-.49808825E-06
6361311	-.15716965E-05
6361320	.41796517E-05
6361321	-.50903363E-05
6361330	.19263030E-05
6361331	-.26559448E-05
6363310	-.16489497E-05
6363310	-.85652890E-05
6363311	.21125294E-05
6363311	.13925639E-05
6363320	-.64335893E-06
6363320	.13296853E-05
6363321	.13987258E-05
6363321	.22084882E-05
6363330	.17683444E-05
6363330	.62309563E-06
6363331	-.42699193E-05
6363331	.30206135E-05
6163310	-.19912899E-05
6163310	.40919536E-05
6163311	.34173222E-05
6163311	-.33408596E-06
6163320	-.42932058E-05
6163320	-.10391861E-05
6163321	.54949702E-05
6163321	-.63112847E-06
6163330	-.20756988E-05
6163330	-.40347403E-06
6163331	-.42797677E-05
6163331	-.20549191E-05
6563310	.35086379E-05
6563310	.47815359E-05
6563311	-.55170146E-05
6563311	-.14639948E-05
6563320	.49807017E-05
6563320	-.47212536E-08
6563321	-.68935330E-05
6563321	-.20120167E-05
6563330	.31523627E-06
6563330	-.16752355E-06
6563331	.86371516E-05
6563331	-.46034989E-06
6365310	-.91736901E-06
6365311	.17170494E-05
6365320	-.11945579E-05
6365321	.18220645E-05
6365330	.83208060E-06
6365331	.26609361E-05
6565310	.91087945E-06
6565311	-.17053559E-05
6565320	.11990887E-05
6565321	-.18287713E-05
6565330	-.83085360E-06
6565331	-.26562696E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
65310	.57086508E+00	-.78137519E-01	-.14642514E-00	.14596972E-05
65311	.56205408E+00	-.84641670E-01	-.14727393E-00	.14349496E-05
65320	.53692224E+00	.88630803E-01	-.14897329E-00	.11175805E-05
65321	.53930527E+00	.89034264E-01	-.14917578E-00	.13983690E-05
65330	.54846629E+00	.50892365E-03	-.14698233E-00	.10706127E-05
65331	.54903813E+00	-.44326984E-02	-.14701733E-00	.21229526E-05

RMS PARALLAX FOR TRIPLET IS .26928170E-05

OBJECT	X	Y	Z	PRECISION
64101	.51013875E+00	.78743011E-01	-.14867232E-00	.23531647E-05
65101	.53322245E+00	.87952933E-01	-.14811613E-00	-.83560287E-05
65102	.53469359E+00	.86832486E-01	-.14803794E-00	.72682381E-05
65103	.54705145E+00	.50846896E-01	-.14799122E-00	-.11879918E-04
64201	.49935179E-00	-.74202697E-01	-.14727433E-00	.11058979E-05
64202	.48640444E-00	.17206909E-01	-.14768329E-00	-.97587724E-05
64203	.47971354E-00	.96866767E-01	-.14951353E-00	.22081476E-05

IMAGE	RESIDUAL X,Y PARALLAX
6563310	.30830644E-05
6563311	-.59865228E-05
6563320	.44630566E-05
6563321	-.74539008E-05
6563330	.39728928E-06
6563331	.87004867E-05
6565310	.10804817E-07
6565310	-.16493406E-05
6565311	-.86186886E-06
6565311	-.11765891E-05
6565320	.12266195E-05
6565320	-.11959483E-05
6565321	-.16137145E-05
6565321	.18321618E-05
6565330	.43979236E-06
6565330	.55100456E-06
6565331	-.39557778E-05
6565331	.10177383E-05
6365310	-.20413046E-05
6365310	.66127129E-06
6365311	.25930594E-05
6365311	.75039913E-06
6365320	-.18189482E-05
6365320	.53054279E-06
6365321	.19395590E-05
6365321	-.86453163E-06
6365330	.15073030E-05
6365330	-.12601203E-06
6365331	.95501285E-06
6365331	-.68959631E-06
6765310	.20792361E-05
6765310	.10660339E-05
6765311	-.16860526E-05
6765311	.31220742E-06
6765320	.64563287E-06
6765320	.74306117E-06
6765321	-.39741900E-06
6765321	-.10509416E-05
6765330	-.19664064E-05
6765330	-.47502617E-06
6765331	.29656269E-05
6765331	-.41840208E-06
6567310	.17845384E-05
6567311	-.61607019E-06
6567320	-.17347760E-05
6567321	.28088992E-05
6567330	-.25753674E-06
6567331	-.35209940E-06
6767310	-.18016819E-05
6767311	.62304649E-06
6767320	.17526791E-05
6767321	-.28344945E-05
6767330	.26089710E-06
6767331	.35639486E-06

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
67310	.66270196E+00	-.80464761E-01	-.14692896E-00	.18226272E-05
67311	.65958781E+00	-.85021949E-01	-.14646996E-00	.11838373E-05
67320	.64304825E+00	.97587518E-01	-.14828096E-00	.24184447E-05
67321	.63646451E+00	.93408413E-01	-.14842689E-00	.18772208E-05
67330	.64974177E+00	.80239767E-02	-.14794334E-00	.18986821E-05
67331	.65068974E+00	.44291091E-02	-.14787219E-00	.18835410E-05

RMS PARALLAX FOR TRIPLET IS .21775514E-05

OBJECT	X	Y	Z	PRECISION
66101	.60058726E+00	.34328562E-01	-.14791425E-00	.20460242E-05

IMAGE	RESIDUAL X,Y PARALLAX
6765310	.29038178E-05
6765311	-.60048246E-06
6765320	.14849730E-05
6765321	.41988782E-06
6765330	-.20288865E-05
6765331	.29180593E-05
6767310	-.11941968E-05
6767310	.20720542E-05
6767311	-.36967357E-06
6767311	-.74839972E-06
6767320	.14625930E-05
6767320	-.41913695E-05
6767321	-.26734611E-05
6767321	-.16875314E-05
6767330	.13991965E-05
6767330	.71373893E-06
6767331	-.36574382E-06
6767331	.36834926E-05
6567310	.29679205E-05
6567310	-.64301835E-06
6567311	-.17151567E-05
6567311	.85581609E-07
6567320	-.24247302E-05
6567320	.17878992E-05
6567321	.30749363E-05
6567321	.10451524E-05
6567330	.22737474E-05
6567330	.64578837E-07
6567331	.86757447E-06
6567331	-.16748614E-05
6967321	.68156163E-06
6967330	-.37197186E-05
6967330	-.39036362E-06
6967331	-.66922166E-06
6967331	-.18917639E-05
6769310	.16973724E-05
6769311	-.30593099E-05
6769320	-.27461764E-05
6769321	.18276507E-05
6769330	-.36764217E-06
6769331	-.68174143E-06
6969310	-.17191979E-05
6969311	.30996173E-05
6969320	.27553922E-05
6969321	-.18345763E-05
6969330	.37060907E-06
6969331	.68732091E-06
6967310	-.19083729E-05
6967310	-.11612031E-05
6967311	.21439916E-05
6967311	.40777108E-06
6967320	.11660890E-05
6967320	.22250456E-05
6967321	-.36944316E-06

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
69310	.75229957E+00	-.72312965E-01	-.14759110E-00	.17672077E-05
69311	.75512144E+00	-.75250082E-01	-.14758741E-00	.23661646E-05
69320	.74186950E+00	.99693089E-01	-.14831319E-00	.32542352E-05
69321	.74096714E+00	.90659767E-01	-.14810360E-00	.20261498E-05
69330	.74590225E+00	.89059674E-02	-.14792924E-00	.26023148E-05
69331	.74472014E+00	.64792074E-02	-.14808967E-00	.19989742E-05

RMS PARALLAX FOR TRIPLET IS .26720223E-05

OBJECT	X	Y	Z	PRECISION
68106	.70434044E+00	.47779501E-01	-.14794899E-00	.44717390E-05
68111	.71934618E+00	.20572955E-02	-.14801160E-00	-.33707108E-05
68112	.72102329E+00	-.22531081E-01	-.14806336E-00	-.89138546E-05
68113	.71806904E+00	-.20365738E-01	-.14779362E-00	.42049020E-05
68114	.71765966E+00	-.14170874E-01	-.14802194E-00	.32986575E-04
68115	.71274156E+00	-.14599216E-01	-.14755590E-00	.39249942E-05
69201	.74521121E+00	-.63400350E-01	-.14795079E-00	-.74762831E-05
69202	.74166691E+00	.12127712E-01	-.14816936E-00	.19831641E-06
69203	.73614447E+00	.10459250E-00	-.14919983E-00	.13198368E-04

IMAGE	RESIDUAL X,Y PARALLAX
6967310	-.18816959E-05
6967311	.21979209E-05
6967320	.11535590E-05
6967321	-.41912471E-06
6967330	-.38598352E-05
6967331	-.80787094E-06
6969310	-.20707050E-05
6969310	-.28175003E-05
6969311	.42004921E-05
6969311	-.21777893E-05
6969320	.33656330E-05
6969320	-.53872231E-05
6969321	-.90521975E-06
6969321	.29699653E-05
6969330	-.77042877E-06
6969330	.48590694E-05
6969331	-.92512282E-06
6969331	.26506889E-05
6769310	.13360178E-05
6769310	.14880609E-05
6769311	-.19312765E-05
6769311	.89613610E-06
6769320	-.30921174E-05
6769320	.22615463E-05
6769321	.28089605E-05
6769321	-.10381159E-05
6769330	-.85454292E-06
6769330	-.25030979E-05
6769331	-.18581688E-05
6769331	-.15999868E-05
7169310	.67072793E-06
7169310	.14362683E-05
7169311	-.22891731E-05
7169311	.11967906E-05
7169320	-.36154965E-06
7169320	.28955352E-05
7169321	-.18723912E-05
7169321	-.15867543E-05
7169330	.17247111E-05
7169330	-.25412136E-05
7169331	.28574471E-05
7169331	-.13840633E-05
6971310	-.23960191E-05
6971311	.11562462E-05
6971320	.23674940E-05
6971321	-.39630272E-05
6971330	.17903692E-05
6971331	.17644436E-05
7171310	.23863126E-05
7171311	-.11520412E-05
7171320	-.23666731E-05
7171321	.39630916E-05
7171330	-.17865647E-05
7171331	-.17608332E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
71310	.83940856E+00	-.77102445E-01	-.14709503E-00	.18621431E-05
71311	.83259877E+00	-.78692773E-01	-.14739851E-00	.36611366E-05
71320	.82688536E+00	.93176628E-01	-.14829613E-00	.17936404E-05
71321	.82177887E+00	.94794191E-01	-.14858916E-00	.59354172E-05
71330	.83233104E+00	.89386428E-02	-.14784785E-00	.72973527E-05
71331	.83039682E+00	.63983625E-02	-.14782062E-00	.30499305E-05

RMS PARALLAX FOR TRIPLET IS .43592721E-05

OBJECT	X	Y	Z	PRECISION
71101	.83161279E+00	.76991575E-01	-.14804231E-00	.50548506E-05
69201	.74521091E+00	-.63415279E-01	-.14797858E-00	.42448603E-05
69202	.74166652E+00	.12130741E-01	-.14818051E-00	.52071651E-05
69203	.73614394E+00	.10460215E-00	-.14920729E-00	-.35365046E-05

IMAGE	RESIDUAL X,Y PARALLAX
7169310	.15065232E-05
7169311	-.14181872E-05
7169320	.27086853E-06
7169321	-.14786237E-05
7169330	.12429278E-05
7169331	.24024083E-05
7171310	.12255611E-05
7171310	.27334866E-05
7171311	-.20528100E-06
7171311	.64901675E-05
7171320	-.16690603E-05
7171320	-.25592704E-05
7171321	.47882492E-05
7171321	.10808317E-04
7171330	-.17754213E-05
7171330	-.14346153E-04
7171331	-.46240072E-05
7171331	-.31570724E-05
6971310	-.24578848E-05
6971310	-.15940430E-05
6971311	.32337354E-05
6971311	-.30974133E-05
6971320	.23819837E-05
6971320	.15082809E-05
6971321	-.29712425E-05
6971321	-.57581234E-05
6971330	.22266135E-05
6971330	.75849119E-05
6971331	.10384147E-06
6971331	.15349501E-05
7371310	.12696773E-05
7371310	-.12795551E-05
7371311	-.28467995E-05
7371311	-.31786523E-05
7371320	-.76727293E-06
7371320	.11957351E-05
7371321	-.15809553E-05
7371321	-.52100213E-05
7371330	-.75610514E-06
7371330	.68908281E-05
7371331	.44319878E-05
7371331	.15666956E-05
7173310	-.41641444E-05
7173311	.27735383E-05
7173320	-.12126693E-05
7173321	-.85024563E-06
7173330	-.19449170E-06
7173331	.33652799E-05
7373310	.41485437E-05
7373311	-.27638587E-05
7373320	.12202933E-05
7373321	.85539326E-06
7373330	.19476043E-06
7373331	-.33697193E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
73310	.92454890E+00	-.81569735E-01	-.14729452E-00	.27658100E-05
73311	.92474706E+00	-.77562439E-01	-.14787415E-00	.19028747E-05
73320	.92035353E+00	.10029875E-00	-.14976850E-00	.25891280E-05
73321	.92420472E+00	.91173930E-01	-.14937559E-00	.21215873E-05
73330	.92465389E+00	.77695036E-02	-.14579056E-00	.27147892E-05
73331	.92190725E+00	.10125595E-01	-.14617966E-00	.26962879E-05

RMS PARALLAX FOR TRIPLET IS .28217646E-05

OBJECT	X	Y	Z	PRECISION
71101	.83161251E+00	.77006986E-01	-.14807304E-00	-.29461142E-05
73101	.91370408E+00	.47497466E-01	-.14846721E-00	.42021316E-05

IMAGE	RESIDUAL X,Y PARALLAX
7371310	.17329012E-05
7371311	-.22854668E-05
7371320	-.37261167E-06
7371321	-.11360824E-05
7371330	-.11313728E-05
7371331	.40710976E-05
7373310	.53184856E-05
7373310	.15140407E-05
7373311	-.29843688E-05
7373311	.16581601E-05
7373320	.97753033E-06
7373320	.49707963E-05
7373321	.27390278E-05
7373321	-.18526076E-05
7373330	-.22945349E-05
7373330	-.35151934E-05
7373331	-.46176568E-05
7373331	-.26806491E-05
7173310	-.26763242E-05
7173310	-.76892985E-06
7173311	.29626424E-05
7173311	-.71967974E-06
7173320	-.14013206E-05
7173320	-.24838810E-05
7173321	.89871901E-06
7173321	.10313506E-05
7173330	-.18570181E-05
7173330	.15620132E-05
7173331	.29598962E-05
7173331	.13602560E-05
7573310	-.26504097E-05
7573310	-.73551620E-06
7573311	.24398872E-07
7573311	-.87969055E-06
7573320	.41332955E-06
7573320	-.25005833E-05
7573321	-.36519996E-05
7573321	.92945593E-06
7573330	.41734304E-05
7573330	.18146860E-05
7573331	.16669377E-05
7573331	.13119500E-05
7375310	.98425003E-06
7375311	-.37954693E-05
7375320	-.19643031E-05
7375321	-.89336845E-06
7375330	.12032856E-05
7375331	.45558212E-05
7575310	-.97817177E-06
7575311	.37730904E-05
7575320	.19683440E-05
7575321	.89490457E-06
7575330	-.12008089E-05
7575331	-.45466804E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
75310	.10107981E+01	-.84097612E-01	-.14643802E-00	.33370595E-05
75311	.10087023E+01	-.79648415E-01	-.14640893E-00	.30684280E-05
75320	.10100563E+01	.98697228E-01	-.14878291E-00	.35635525E-05
75321	.10127915E+01	.93340995E-01	-.14909259E-00	.36353159E-05
75330	.10104919E+01	.63965680E-02	-.14796770E-00	.30159727E-05
75331	.10079924E+01	.55418386E-02	-.14799438E-00	.25313471E-05

RMS PARALLAX FOR TRIPLET IS .34188947E-05

OBJECT	X	Y	Z	PRECISION
73101	.91370532E+00	.47492361E-01	-.14844769E-00	-.34882446E-05
75101	.10279046E+01	.24706813E-01	-.14814656E-00	-.12319720E-05
75201	.10171811E+01	.93146066E-01	-.14906997E-00	.40465920E-06
75202	.10231662E+01	.12166004E-01	-.14858534E-00	.74912917E-05
75203	.10107997E+01	-.89452611E-01	-.14672884E-00	.41461332E-05

IMAGE	RESIDUAL X,Y PARALLAX
7573310	-.40775322E-05
7573311	-.12429223E-05
7573320	-.99608989E-06
7573321	-.46614958E-05
7573330	.47073310E-05
7573331	.21380151E-05
7575310	.59857929E-06
7575310	-.60556115E-05
7575311	.19564999E-05
7575311	.51757818E-07
7575320	-.19749264E-07
7575320	-.51836736E-05
7575321	.26389287E-05
7575321	.63012160E-05
7575330	-.22295776E-05
7575330	.45974171E-05
7575331	-.21334510E-05
7575331	.35736794E-06
7375310	.19510136E-05
7375310	.32517482E-05
7375311	-.60056533E-05
7375311	-.34126486E-06
7375320	-.42871059E-05
7375320	.23649170E-05
7375321	.90090810E-06
7375321	-.31052082E-05
7375330	-.15638576E-05
7375330	-.25211374E-05
7375331	.50276967E-05
7375331	.85843897E-07
7775310	-.25904920E-05
7775310	.29489149E-05
7775311	.40577787E-05
7775311	.10501873E-06
7775320	.42992674E-05
7775320	.26204514E-05
7775321	-.35199395E-05
7775321	-.31272888E-05
7775330	.38318159E-05
7775330	-.22326420E-05
7775331	-.29004908E-05
7775331	-.26274279E-06
7577310	.19172800E-05
7577311	.11757820E-05
7577320	-.10162567E-06
7577321	.30418323E-05
7577330	.47587137E-06
7577331	-.33523472E-05
7777310	-.19238897E-05
7777311	-.11811915E-05
7777320	.10101878E-06
7777321	-.30248329E-05
7777330	-.47542901E-06
7777331	.33500828E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
77310	.11027531E+01	-.84354799E-01	-.14717901E-00	.52548188E-05
77311	.10961174E+01	-.95302445E-01	-.14660103E-00	.28095934E-05
77320	.11027229E+01	.91497783E-01	-.14918502E-00	.17532627E-05
77321	.11029258E+01	.84056404E-01	-.14935879E-00	.30744801E-05
77330	.10996842E+01	.10757402E-02	-.14903725E-00	.45432653E-05
77331	.11004813E+01	-.48244387E-02	-.14914504E-00	.21924884E-05

RMS PARALLAX FOR TRIPLET IS .36893490E-05

OBJECT	X	Y	Z	PRECISION
75101	.10279031E+01	.24705520E-01	-.14813402E-00	.24086263E-05
76101	.10390832E+01	-.85811425E-01	-.14529203E-00	-.12883851E-05
75201	.10171823E+01	.93160056E-01	-.14909497E-00	-.28849947E-05
75202	.10231681E+01	.12164977E-01	-.14860771E-00	-.12444613E-04
75203	.10107998E+01	-.89471752E-01	-.14675149E-00	-.13936380E-04

IMAGE	RESIDUAL X,Y PARALLAX
7775310	-.16865880E-05
7775311	.48563705E-05
7775320	.52749793E-05
7775321	-.27304716E-05
7775330	.34741110E-05
7775331	-.32255801E-05
7777310	-.33302533E-05
7777310	.99302257E-05
7777311	.72273439E-06
7777311	-.45367509E-05
7777320	-.24759080E-06
7777320	-.34905744E-05
7777321	-.31312338E-05
7777321	.45383411E-05
7777330	.36058628E-06
7777330	-.85779669E-05
7777331	.13133977E-05
7777331	.19457544E-05
7577310	.11211511E-05
7577310	-.50831562E-05
7577311	.23933151E-05
7577311	.24323216E-05
7577320	.87847657E-08
7577320	.17924171E-05
7577321	.39684084E-05
7577321	-.21762568E-05
7577330	.22945101E-05
7577330	.45083050E-05
7577331	-.38438405E-05
7577331	-.11570152E-05
7977310	.23316554E-05
7977310	-.48421775E-05
7977311	-.31832623E-05
7977311	.21168688E-05
7977320	.19456581E-06
7977320	.17168221E-05
7977321	-.75643621E-06
7977321	-.22927817E-05
7977330	-.27617852E-05
7977330	.41132674E-05
7977331	.25515405E-05
7977331	-.84077643E-06
7779310	-.22665821E-05
7779311	-.52515189E-08
7779320	.73970682E-06
7779321	-.28731076E-05
7779330	.30399523E-05
7779331	-.24051797E-06
7979310	.22720731E-05
7979311	.52641494E-08
7979320	-.74182023E-06
7979321	.28814620E-05
7979330	-.30478447E-05
7979331	.24116834E-06

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
79310	.11921975E+01	-.92699266E-01	-.14808104E-00	.21602416E-05
79311	.11922917E+01	-.97408689E-01	-.14780371E-00	.15626153E-05
79320	.11926939E+01	.84443592E-01	-.14852323E-00	.40348860E-05
79321	.11951786E+01	.77607726E-01	-.14886401E-00	.49393948E-05
79330	.11920874E+01	-.74563923E-02	-.14965842E-00	.20590307E-05
79331	.11958080E+01	-.87540093E-02	-.14965273E-00	.18926383E-05

RMS PARALLAX FOR TRIPLET IS .31294962E-05

OBJECT	X	Y	Z	PRECISION
78101	.11530783E+01	-.71180112E-02	-.14866590E-00	-.22409138E-05

IMAGE	RESIDUAL X,Y PARALLAX
7977310	.22957630E-05
7977311	-.32318902E-05
7977320	.45723166E-07
7977321	-.87938241E-06
7977330	-.27344382E-05
7977331	.25833745E-05
7979310	.69962525E-06
7979310	.21818568E-05
7979311	.12234158E-05
7979311	-.17195330E-05
7979320	-.45337261E-05
7979320	.13542930E-05
7979321	.76524991E-05
7979321	-.53144241E-06
7979330	-.19417064E-05
7979330	.88018769E-06
7979331	-.11613670E-05
7979331	-.21023889E-05
7779310	-.35216175E-05
7779310	-.11595698E-05
7779311	.13836371E-05
7779311	.90658700E-06
7779320	-.33559628E-05
7779320	-.82679798E-06
7779321	.15137529E-05
7779321	.43684347E-06
7779330	.40089925E-05
7779330	-.36170981E-06
7779331	-.19281335E-05
7779331	.95757102E-06
8179310	.28304194E-05
8179310	-.99610418E-06
8179311	-.26114018E-05
8179311	.80080505E-06
8179320	.79405101E-05
8179320	-.54338174E-06
8179321	-.92217981E-05
8179321	.13678792E-06
8179330	-.20935533E-05
8179330	-.55395922E-06
8179331	.31213218E-05
8179331	.11603345E-05
7981310	.13359331E-05
7981311	-.75290705E-06
7981320	.22405540E-05
7981321	-.23145676E-05
7981330	-.25776235E-05
7981331	.20323268E-05
8181310	-.13355463E-05
8181311	.75253576E-06
8181320	-.22432709E-05
8181321	.23188499E-05
8181330	.25786388E-05
8181331	-.20334925E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
81310	.12814900E+01	-.95995762E-01	-.14766159E-00	.32390270E-05
81311	.12842648E+01	-.10144869E-00	-.14821156E-00	.25688519E-05
81320	.12939868E+01	.75321044E-01	-.14909922E-00	.24695248E-05
81321	.12816039E+01	.77704576E-01	-.14902296E-00	.18386780E-05
81330	.12885256E+01	-.12862633E-01	-.14929517E-00	.13263475E-05
81331	.12850574E+01	-.12108245E-01	-.14917432E-00	.31180085E-05

RMS PARALLAX FOR TRIPLET IS .34600297E-05

OBJECT	X	Y	Z	PRECISION
81101	.12702373E+01	.15032234E-01	-.14936670E-00	.10086739E-04
81201	.12702783E+01	-.11089846E-00	-.14705106E-00	.15405759E-05
81202	.12713770E+01	-.28289613E-01	-.14937923E-00	.50698207E-05
81203	.12609343E+01	.61918635E-01	-.14901852E-00	-.53596084E-05

IMAGE	RESIDUAL X,Y PARALLAX
8179310	.44692915E-05
8179311	-.77506964E-06
8179320	.95845311E-05
8179321	-.78835740E-05
8179330	-.22351719E-05
8179331	.29016102E-05
8181310	.15050043E-06
8181310	.46316467E-05
8181311	-.19420451E-05
8181311	.20716725E-05
8181320	-.18242442E-05
8181320	-.40761328E-05
8181321	.17455789E-05
8181321	-.20822629E-05
8181330	.24725976E-05
8181330	-.27895463E-06
8181331	-.58454838E-06
8181331	-.45054815E-06
7981310	.38374522E-05
7981310	-.21732266E-05
7981311	-.27272726E-05
7981311	-.11228713E-05
7981320	.27268878E-05
7981320	.20800373E-05
7981321	-.30212357E-05
7981321	.94760616E-06
7981330	-.44077409E-06
7981330	.14794253E-06
7981331	.56504151E-05
7981331	.38595218E-06
8381330	.10461698E-06
8381331	-.50705841E-05
8381331	.14098970E-07
8183310	.24478312E-05
8183311	-.48635618E-05
8183320	-.24607024E-05
8183321	-.43746992E-07
8183330	.12674070E-05
8183331	-.24098088E-05
8383310	-.24582877E-05
8383311	.48843208E-05
8383320	.24590288E-05
8383321	.43723055E-07
8383330	-.12699273E-05
8383331	.24143042E-05
8381310	-.39609400E-05
8381310	-.25169375E-05
8381311	.46933249E-05
8381311	-.89692779E-06
8381320	-.93309759E-06
8381320	.20038579E-05
8381321	.12624366E-05
8381321	.11322484E-05
8381330	-.20338434E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
83310	.13741453E+01	-.10555860E-00	-.14901741E-00	.34942890E-05
83311	.13779850E+01	-.10343409E-00	-.14982676E-00	.41856171E-05
83320	.13798417E+01	.77087003E-01	-.15115593E-00	.31712561E-05
83321	.13804140E+01	.72070094E-01	-.15102966E-00	.29007514E-05
83330	.13780633E+01	-.21537436E-01	-.15055634E-00	.76448540E-06
83331	.13796028E+01	-.16028906E-01	-.15075914E-00	.32246758E-05

RMS PARALLAX FOR TRIPLET IS .33230828E-05

OBJECT	X	Y	Z	PRECISION
81101	.12702403E+01	.15029631E-01	-.14934190E-00	-.55659959E-05
83101	.13539794E+01	.25987951E-01	-.14982946E-00	-.67139380E-05
81201	.12702771E+01	-.11090994E-00	-.14706073E-00	-.11523990E-04
81202	.12713759E+01	-.28291360E-01	-.14938882E-00	-.66765597E-05

IMAGE	RESIDUAL X,Y PARALLAX
8381310	-.52551820E-05
8381311	.32501064E-05
8381320	-.21080808E-05
8381321	-.21924195E-06
8381330	-.18195350E-05
8381331	-.49139455E-05
8383310	.53853222E-06
8383310	-.24702213E-05
8383311	.19602219E-05
8383311	-.93059280E-06
8383320	.47482574E-05
8383320	.34342330E-05
8383321	-.21179582E-05
8383321	.35713616E-05
8383330	-.10908372E-05
8383330	-.38382657E-06
8383331	.12797213E-05
8383331	-.29506993E-05
8183310	.53743361E-05
8183310	.13299849E-05
8183311	-.79575403E-05
8183311	.34661860E-06
8183320	-.28247831E-06
8183320	-.16516805E-05
8183321	-.24838302E-05
8183321	-.18483773E-05
8183330	-.31842122E-06
8183330	.17177347E-06
8183331	-.54576456E-05
8183331	.13970168E-05
8583310	-.59230996E-05
8583310	.10643625E-05
8583311	.60417125E-05
8583311	.68043345E-06
8583320	-.44773517E-05
8583320	-.17739129E-05
8583321	.45654387E-05
8583321	-.16782845E-05
8583330	.14111552E-05
8583330	.21707514E-06
8583331	.42045716E-05
8583331	.16220097E-05
8385310	.21400575E-05
8385311	.75988672E-06
8385320	.31017500E-05
8385321	-.83270799E-06
8385330	.16291686E-05
8385331	-.10955136E-05
8585310	-.21392036E-05
8585311	-.75962143E-06
8585320	-.30918325E-05
8585321	.83004826E-06
8585330	-.16265521E-05
8585331	.10936833E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
85310	.14671304E+01	-.98419130E-01	-.15045169E-00	.25808523E-05
85311	.14617414E+01	-.98407050E-01	-.15006825E-00	.21613553E-05
85320	.14648890E+01	.70875763E-01	-.14725547E-00	.51048990E-05
85321	.14693140E+01	.68322271E-01	-.14748489E-00	.41713233E-05
85330	.14657260E+01	-.22507687E-01	-.15189230E-00	.45744655E-05
85331	.14668425E+01	-.19386067E-01	-.15151387E-00	.40553873E-05

RMS PARALLAX FOR TRIPLET IS .42217090E-05

OBJECT	X	Y	Z	PRECISION
85101	.14432072E+01	-.11960002E-01	-.15098546E-00	-.17881929E-05

IMAGE	RESIDUAL X,Y PARALLAX
8583310	-.55982642E-05
8583311	.63296310E-05
8583320	-.41838844E-05
8583321	.48069596E-05
8583330	.12475624E-05
8583331	.40336561E-05
8585310	.21824895E-07
8585310	.62954396E-07
8585311	-.26194201E-05
8585311	.23660469E-05
8585320	-.39824041E-06
8585320	.75661694E-05
8585321	-.16662206E-05
8585321	-.64960966E-05
8585330	.13557781E-05
8585330	-.64819443E-05
8585331	-.30322253E-05
8585331	.27335856E-05
8385310	.44670143E-05
8385310	.54854900E-07
8385311	-.86349080E-06
8385311	-.12125535E-05
8385320	.61616400E-05
8385320	-.36522493E-05
8385321	-.34973630E-05
8385321	.31586360E-05
8385330	.48406344E-05
8385330	.33224139E-05
8385331	-.45983037E-05
8385331	-.14662515E-05
8785310	-.44716863E-05
8785310	-.84545784E-07
8785311	.34633528E-05
8785311	-.11655409E-05
8785320	-.56889699E-05
8785320	-.39096463E-05
8785321	.51057875E-05
8785321	.33386331E-05
8785330	-.61305883E-05
8785330	.31058622E-05
8785331	.75615386E-05
8785331	-.12405474E-05
8587310	.89670879E-06
8587311	-.24583373E-05
8587320	.30117399E-05
8587321	-.35710859E-05
8587330	-.31623135E-07
8587331	.20369487E-05
8787310	-.90319201E-06
8787311	.24749816E-05
8787320	-.30091389E-05

N E W T R I P L E T

PASS PT	X	Y	Z	PRECISION
87310	.15547110E+01	-.10830302E-00	-.15260555E-00	.89670879E-06
87311	.15526836E+01	-.10413071E-00	-.15298785E-00	-.24583373E-05
87320	.15583441E+01	.65431087E-01	-.15159718E-00	.30117399E-05
87321	.15607373E+01	.67830643E-01	-.15061562E-00	-.35710859E-05
87330	.15582184E+01	-.27875887E-01	-.15489962E-00	-.31623135E-07
87331	.15571583E+01	-.27276497E-01	-.15488082E-00	.20369487E-05

OBJECT	X	Y	Z	PRECISION
86101	.15003767E+01	-.40978735E-01	-.15208533E-00	.40557595E-05
87101	.15693540E+01	-.97442138E-01	-.15317438E-00	-.34748141E-05
86201	.15061509E+01	-.10425217E-00	-.15129183E-00	.74525893E-05
86202	.15012441E+01	-.52430672E-01	-.15210173E-00	.98865963E-05
86203	.14972888E+01	.31239519E-01	-.15492201E-00	.39045724E-05

** STRIP ANALYTIC AEROTRIANGULATION COMPLETED **

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