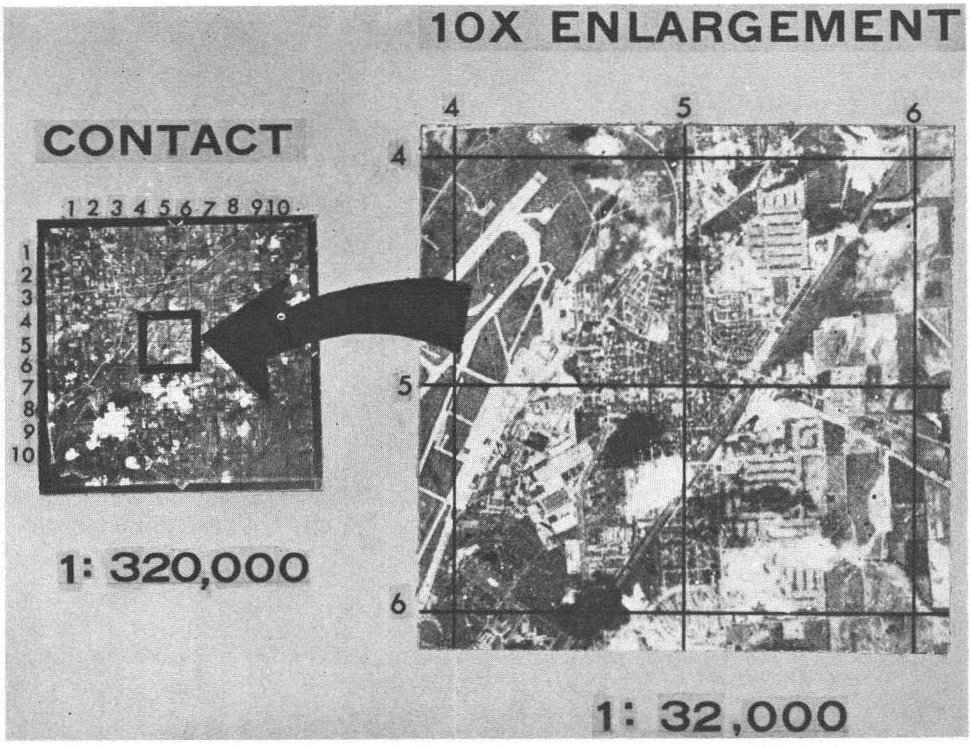


FRONTISPIECE. Segmented mensuration. (See text on page 871.)

ARNOLD F. TRACHSEL*
Aeronautical Chart & Information Center
St. Louis, Missouri

Reseau Techniques

Application of reseau techniques to cartographic photography can improve analytical procedures, reduce mensuration errors, and aid in automating systematic corrections

(*Abstract on page 871*)

ANALYTICAL AEROTRIANGULATION methods are dependent upon precise cameras, lens, and mensuration data to provide the corrections which can be consolidated into the computer program. Considerable time and effort has been expended in improving cameras, reducing lens distortions, calibrating lenses and fiducial marks, improving film stability, computing air refraction corrections, and in improving mensuration accuracy. Such improvements have been made necessary because of the trend toward smaller scale, higher resolution photography. Complete removal of all inherent errors is not possible due to the many variables present. Correcting the measured photographic co-

* Presented at the Annual Convention of the American Society of Photogrammetry at Washington, D. C., March, 1965. The views expressed herein are those of the author and should not be construed as establishing U. S. Air Force doctrine.

ordinates through the use of reseaus is one method which can materially improve analytical reduction procedures.

Reseaus in aerial cameras have been used by the British Ordnance Survey since before 1939 and for many years before that by many leading astronomers. An example of the type of reseau used by the Ordance Survey is shown in Figure 1. The center cross of the reseau is the principal point of the camera. This one centimeter reseau was calibrated to a standard error of about five microns and

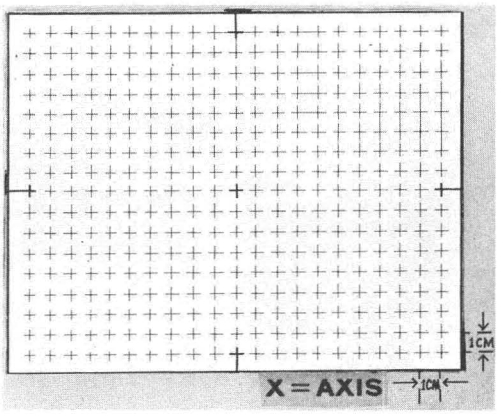


FIG. 1. British Ordnance Survey Reseau.

provided for eliminating most of the normal errors of film shinkage and lens distortion.

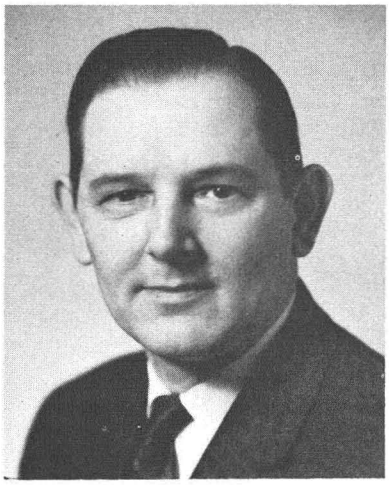
The KC-6A is an Air Force camera which has incorporated a reseau with grid intersections at two inch intervals. The Wild RC5a, the T-11, and a number of other cameras, have corner fiducial marks, Figure 2, which serve as an external reseau. Many variations of external reseaus are possible. To a large extent, such reseaus are primarily used to correct differential scale variations, but provide little information as to local film or lens distortions.

Various tests of reseaus have been performed by ACIC using dots, lines, crosses, etc. Our experience with dot reseaus of 30 micron image size indicated that dots are difficult to identify, locate, and measure. The precision of locating the center of the dot is not as good as locating the intersections of lines. For the scribed line reseau, a line weight of 15 microns has been found to be the most practicable. The center of the intersections of heavier lines are more difficult to determine and are, therefore, less precise. Heavier lines also cause interference in observing stereo models. If the line weights are less than 15 microns, the photographic reproduction of the lines becomes a problem when they are superimposed on a variable density background such as an aerial photograph. The interval of the reseau will be dictated by the scale of the photography and its intended use, but should be kept to a minimum number of lines. In lieu of not having a reseau in the aerial camera, ACIC has been superimposing a scribed reseau, Figure 3, on the copy negative prior to mensuration. This grid has a format large enough to contact print on any size photograph required. The interval is one centimeter, the line weight about 20 microns, and the precision of calibration is two microns.

Aligning the reseau with the photographic fiducial marks does not need to be precise for the superimposed reseau since the measured coordinates of both the reseau and fiducials are adjusted to the calibrated coordinates. For a given camera, the corrections for lens distortion, film shrinkage, principal point shift, etc. can be incorporated into the reseau calibration. An adjustment of the measured reseau to the calibrated reseau will automatically correct for translation and rotation between the comparator and photographic reference axis.

How, one might ask, can all this extra mensuration, adjusting, increased precision, etc. be applied without greatly increasing the manhours required for analytical triangulation procedures, chart revisions, or intelligence annotations? The answer is to eliminate as many of the manual data handling steps as possible by incorporating them into computer programs.

Area identification for partial reproductions



ARNOLD F. TRACHSEL

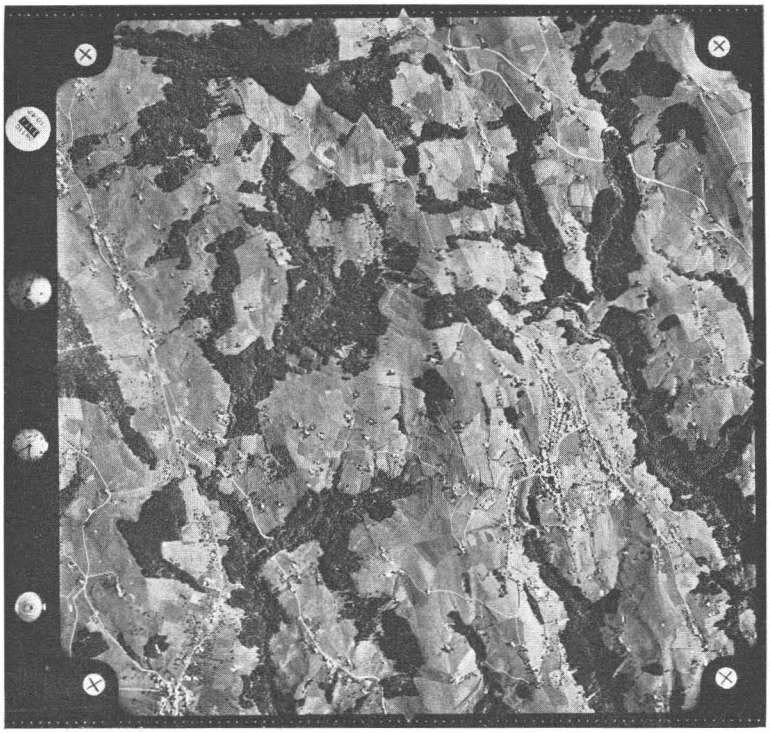


FIG. 2. Wild RC5a fiducial (corner reseau) marks.

(enlargements, rectifications, and copying) can be accomplished on either frame or panoramic photography by specifying the reseau numbers, rows and columns, which surround the specific point or area desired. Figure 4 shows a frame reseau reference system. The numbering system corresponds to matrix rotation. The same reseau applied to panoramic photography is shown by Figure 5. Segmented mensuration using enlarged areas of a photograph can materially increase the accuracy of coordinate measurements from high quality, small scale photography which has been photographically enlarged a number of diameters.

Another application of reseaus is in the area of rectification. The precise coordinates of each desired reseau intersection can be precisely computed without measuring each of their photographic coordinates, assuming that the tilt data is available, by any of the conventional mathematical rectification procedures. In most cases, the values of elevations of the points will not be known and relief displacements cannot be corrected. It is necessary to measure at least two reseau points and the fiducial marks in order to translate and rotate the comparator coordinate system into the calibrated reseau and to establish a common origin at the photographic principal point. The rectification can include corrections for the known errors of lens distortion, film shrinkage, earth curvature, refraction, etc. Such rectifications can be plotted to provide a good relative base from

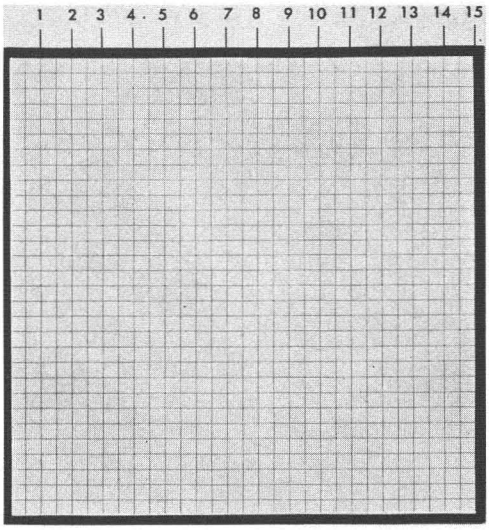


FIG. 3. A scribed reseau.

small scale photography such as was shown by Figure 4. This photograph was taken from about 40,000 feet with a $1\frac{1}{2}$-inch focal length for a scale of 1:320,000. Other uses could be for control of selected areas, intelligence applications or resections and positioning of other larger scale photo identifiable detail points.

Application of reseaus to analytical triangulation procedures involves a number of techniques for expeditious data handling. Local distortions for a given camera can be determined by selecting a representative sample of the photography or each exposure if necessary, orienting on a first order stereo plotting instrument, such as the Wild A-7, and measuring the residual Y-parallax at regular intervals, 2 to 3 centimeters, throughout the model area. Corrections for these distortions are then incorporated into the calibrated reseau.

ABSTRACT: *The application of reseau techniques to any cartographic photography can materially improve analytical reduction procedures by reducing mensuration errors and by automating the normal corrections for lens distortion, film shrinkage, refraction, local distortions, etc. Superimposing a calibrated grid on such photography can provide many of the advantages normally associated with photography from a reseau camera. Types of reseaus, intervals, and line weights have various applications at ACIC.*

A mensuration routine for reseaued photography has been developed for a three-carriage stereocomparator (Nistri TA-3) and a digital computer which permits photo coordinate measurements from either a contact plate of the original material or from any enlargement which the photographic quality of the original material will support. The Frontispiece shows a 10× enlarged area from a small scale photograph. The line weight of the reseau in this example is much heavier than should be used. The physical limitation for using enlarged plates on the TA-3 is that at least four reseau intersections surrounding a point to be measured must be within a 9×9-inch plate. However, economics, resolution of photography, and mensuration time would not permit enlarging to such an extent. The general procedure on the TA-3 is to:

1. Assemble plates in order.
2. Type in required photo data.
3. Measure monoscopically and record the identification and coordinates of two reseau intersections (normally the lower left and upper right corners).
4. Measure and record the coordinates of the four reseau intersections around each point and the point itself.

The computer coordinate reduction program which uses these data generally follows these steps:

1. Read and edit data.
2. Collate data.
3. Sort by plate and point number.
4. Average all multiple readings of data points whose coordinates are within the pre-set accuracy limits.
5. Match identified reseaus with calibrated reseaus.
6. Perform a conformal linear adjustment to translate and rotate the measured coordinate data into the calibrated reseau system which has been corrected for lens distortion.
7. Match external reseaus with calibrated reseaus. This calibration data has not been corrected for lens distortion since it is exposed along the camera frame and not through the lens.
8. Perform a nonconformal hyperbolic adjustment of the measured reseau intersections around a point (four or more) to the calibrated reseau by:

$$X = a_0 + a_1x + a_2y + a_3xy$$

$$Y = b_0 + b_1x + b_2y + b_3xy.$$

9. Use the adjustment coefficients determined in Item 8 above to derive the related data point value.

In computer jargon, this procedure might be better understood by Figure 6. This flow chart of the Stereocomparator Reduction Phase shows the steps of the system. Steps 3 to 5 perform the adjustment to the external reseau, by exposure, and removes the effects of film shrinkage. Recapturing the original photo configuration is only a matter of proper merger of the data based upon the exposure identification number and the master reseau

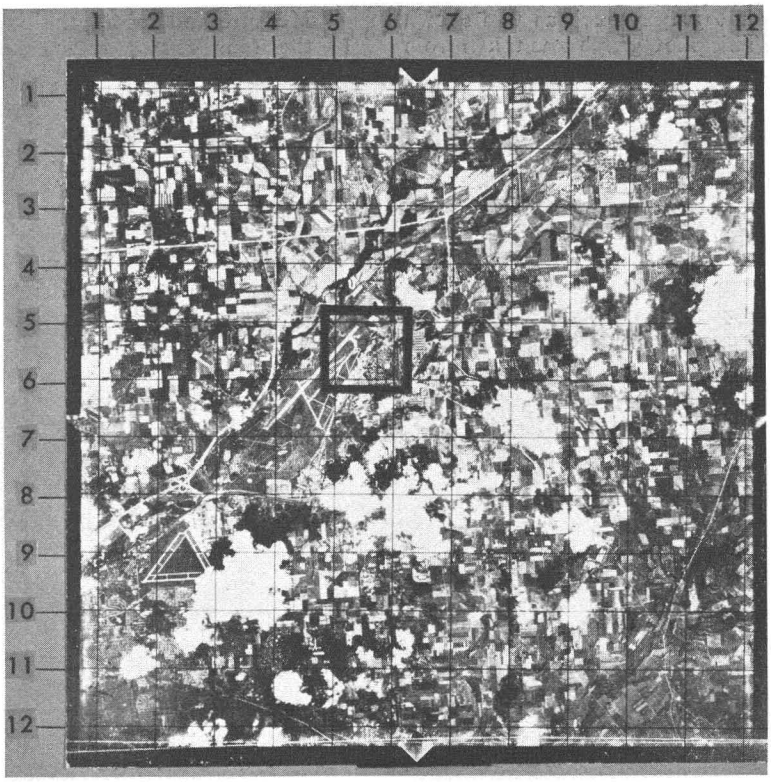


FIG. 4. A frame reseau reference system.

data file. This procedure permits enlarging the original material to the limit of its resolution capabilities in either one or a number of segments. The 9×9-inch comparator plate only limits the segment size.

Another important use of reseaus in analytical triangulation procedures is for the location of pass points, Figure 7. The numbering system permits easy location and identification of any point within a strip. Pointing and stereo point transfer of a 15 to 20-micron reseau intersection can be accomplished in less than one half the time normally required to locate and transfer a detail point due to the ease of locating the pass points at given intervals, to the ease and accuracy of setting the instrument on a fine grid intersection and to utilizing a "tailor made" numbering system.

An evaluation of the accuracy improvement which can be obtained using reseau mensuration techniques shows that an eight to ten-micron comparator can provide accuracies of five microns at the plate scale. When this system is coupled with enlarged segmented reseau technique, measuring accuracies of one to two microns, at the original photo scale, can be achieved. Combined with the increased coordinate measuring accura-

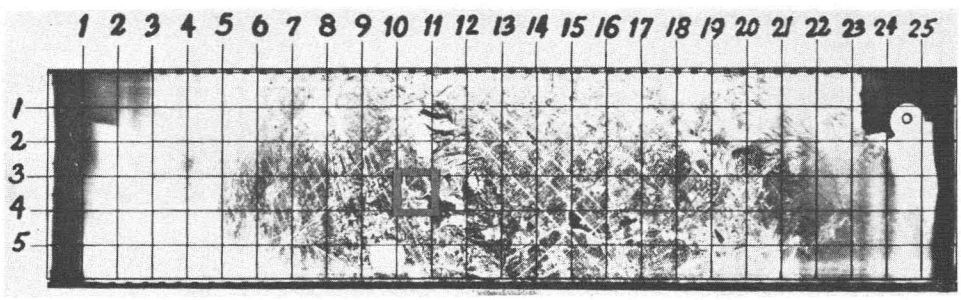


FIG. 5. A panoramic reference system.

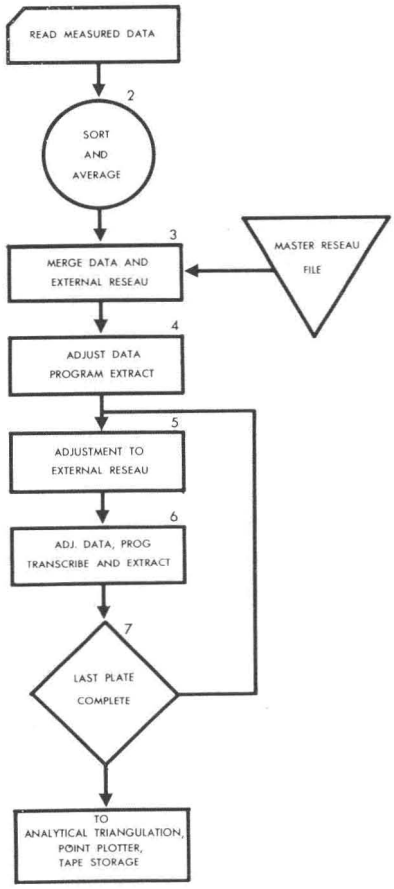


FIG. 6. Flow chart of the stereocomparator reduction phase.

cies is the improved pointing accuracies. It has been generally found from measuring stellar images and grids that a measuring reticle can be positioned over a point such as a star image or grid to within an accuracy of 1/10 the diameter of the point. For a 20-micron grid, this would mean a two micron pointing error. The additional corrections pointed out before, i.e., local film distortions, lens calibration, etc. can be incorporated into the digital computer program to provide greater accuracy, and easier and faster data handling operations for analytical reduction procedures.

From the user's point of view, the ideal place to incorporate a reseau is in the original aerial camera. Superimposing the reseau in the photographic laboratory is the next best alternative which can provide many of the corrections normally obtained from a reseaued camera. The general techniques described can be applied to either the reseaued photography or to the superimposed reseau.

REFERENCES

Arthur, D. W. G., "A Stereocomparator Technique for Aerial Triangulation," *Ordnance Survey Professional Papers*, New Series No. 20, 1955.

Fleming, E. A., "Recognition of Air Survey Lens Types," *The Canadian Surveyor*, March 1960.

Livingston, R. G., "A History of Military Mapping Camera Development," *Photogrammetric Engineer*, January 1964.

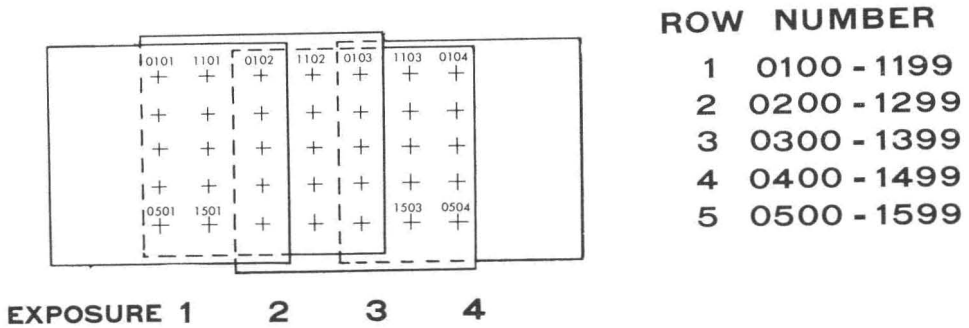


FIG. 7. Reseau intersections used as pass points.