involved in a great many engineering problems which can be limited to two dimensions. This basically is the reason photogrammetric problems, such as mapping, have been solved primarily by analogue instruments such as the multiplex, the Wild autograph, and the stereoplanigraph. With the advent of a new, more powerful tool, namely high-speed electronic computers, it is time to again re-evaluate the processes which have been followed in photogrammetry.

The medium-capacity electronic computer appears to be quite satisfactory for all but the most complex problems involving very large areas and requiring a very large storage capacity or "memory." With a storage capacity of 1,000 or 2,000 ten-digit "words" and performing operations at the rate of approximately 70,000 per hour, it is economically feasible to determine ground positions of any points from photo images with results at least equal to the accuracy required for plotting. If such points can be located at this rate, they may well provide the control which would enable less elaborate machines to be employed by operators with less technical skill for final map compilation. All the techniques of these operations obviously have not been completely worked out to date. However, photogrammetrists are making rapid strides in this direction, and in the near future sufficient data should be available to enable critical comparisons to be made and conclusions drawn profoundly affecting photogrammetric operations.

USE OF LARGE CAPACITY COMPUTERS IN PHOTOGRAMMETRY*

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THERE seems to be no absolute criteria for defining large or small capacity computers. I have a vague idea that UNIVAC is what is known as a large capacity electronic digital computer. In this paper I will discuss the use of UNIVAC. Specifically, its use for the adjustment of Aerotriangulation at the Army Map Service. The capacity of our UNIVAC is something of which I know very little but I do have knowledge of the uses we have made for the adjustment of Aerotriangulation.

Generally speaking, evaluations of equipment by users are usually influenced by particular environmental factors. One often finds a wide range of efficiencies being obtained, from the same types of equipment. More specifically, the efficiency of equipment is greatly dependent upon how well it is adapted to the various situations in which it is used. So without reference to the many other uses we have for UNIVAC at Army Map Service, I shall attempt to describe our basis for use of the UNIVAC in Aerotriangulation. You may then judge its utility for that operation.

Very early in the course of plotting and adjusting the results of planimetric stereo triangulation, it was recognized that a completely numerical recording and adjusting system was possible. It certainly has been well known for many years that most high order Aerotriangulation instruments are equipped with digital counters for recording X, Y and Z. These digital counters provide the means for completely numerical solutions independent of graphical plotting or mechanical templets. Under such conditions the precision of stereo Aerotriangulation need depend only upon the precision of the numerical data recorded and upon the number of decimal places to which computations are carried out.

Although these possibilities for extensive use of numerical stereo triangulation have been known for a long time, practical use

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has been limited to special environments and circumstances. Practical use of the numerical system involves repetitious arithmetic and consumes fairly high cost man-hours. As a result of these practical obstacles much of the production work in planimetric triangulation has taken the form of graphical or mechanical solutions.

Use of graphical plotting or mechanical templets to determine errors or to adjust Aerotriangulation necessarily limits the precision of the measuring system to the precision of the graphical or mechanical system. In view of the very great emphasis given to high precision of all other elements of the photogrammetric system, it seems inconsistent to restrict the accuracy of a well integrated and highly refined system to the lower order of precision represented by graphical plotting or mechanical templets. This is particularly true in Aerotriangulation. Therefore, it is reasoned, in order to fully realize the accuracy of the stereoplotting system, it is desirable to eliminate all measurement that is external to the photo measurement. This can be accomplished to a larger degree in stereo triangulation if one uses numerical solutions only.

The AMS acquisition of UNIVAC in 1952 appeared to provide an efficient means of practically allowing the use of a completely numerical system without aggravating the computation problem in the adjustment of Aerotriangulation. This no doubt will eventually be true without reservations, but here it is 1955 and we are not yet able to give detailed information on our efficiency. But certainly we are far along in achieving over-all gains in the sense that we have eliminated graphical plots and mechanical templets. But there remains much to be done.

At the present time, we use automatic computation for all of our horizontal Aerotriangulation. We employ second degree equations for the corrections, solving them by the method of least squares. Ease of computation now enables us to rerun several solutions on each strip until we are satisfied. It also makes available more time for analysis of those conditions which are not in accordance with the normal distribution of errors.

Briefly, our present procedures consist of a quadratic and linear X, Y scale transformation of the instrument coordinates to fit a given geodetic coordinate system. This requires just enough tedious arithmetic to make it uneconomical on a desk calculator. The vertical triangulation adjustment is presently accomplished graphically. In the near future it is planned to use a mathematical vertical adjustment also, in which the UNIVAC would be employed for the mathematical computations.

A close study of our present procedures for processing the data reveals considerable possibility for streamlining. I mention briefly such things as automatic recording of the coordinates on tape or cards, and automatic plotting of the adjusted coordinates for use in stereo compilation. In addition we anticipate the simultaneous solution of entire project areas both in X, Y and Z where the number of stereo models is 1,000 or more. But in spite of the fact that we have not fully streamlined our data handling or completely programmed the vertical adjustment, we estimate that our efficiency in Aerotriangulation has been increased by a factor of about 1.5. This we think is quite significant in an agency that uses about 60,000 man-hours per year on Aerotriangulation alone.

It is difficult to estimate gains in accuracies. However, it is believed that automatic computation will certainly provide more homogeneous results and possibly more accuracy. In addition it should certainly reduce the size of the working force required to carry the computational work load. Therefore it should also reduce the problems of training a fairly large group in moderately complex procedures. The Army Map Service will likely continue to exploit the use of electronic tools in the conduct of its mapping operations. It offers its experience in this area to any with a like propensity.