FACTORS AFFECTING THE COST OF STEREOSCOPIC CONTOUR MAPPING

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THE foundation of any stereoscopic mapping project lies in the quality of the flying. If the foundation is well laid, the economies resulting are apparent through the entire structure which rests upon it. If, on the other hand, the foundation is badly done, it will prove costly throughout the balance of the structure.

It is indeed a very short look back to the time when an aerial map was considered to be acceptably flown as long as there were not any gaps. In those days the resulting aerial map, like the flying itself, was considered to be good enough as long as the errors and inaccuracies were sufficiently obscure so as not to be painful to the eye.

Today we know that so simple a thing as progressive overlap becomes an all important cost factor in pictures which are to be used for stereo-plotting. It would be ideal in most systems if the picture overlap could run 52% or 53%. The number of pictures to cover a given area, the amount of ground control required, the number of setups, and the amount of laboratory photographic work are all a function of the number of pictures. Furthermore, as the progressive overlap increases, the base altitude ratio becomes less favorable, which again will influence the amount of ground control required.

Ordinarily speaking, the pilot who flies by memory from landmark to landmark is going to do a considerable amount of weaving around to keep approximately on the desired line. Inevitably, this will result in irregularities of overlap and an unnecessarily high degree of crab and tilt. The first requirement, then, to keep the costs of stereoscopic mapping down, is to have a stable airplane handled by a smooth pilot who can fly straight and parallel strips, backed by an alert experienced photographer who will secure pictures which are as nearly perfect as possible.

The second factor of cost in stereoscopic mapping which is common to practically all methods is a carefully planned distribution of control. It has been our experience that it costs little, if any more, to put in an abundance of control in a well planned system than it does to put in less scattered control. The control system should be planned by an expert both in the subjects of surveying and photogrammetry. A surveyor not familiar with stereoscopic plotting is apt to get a lot of control in places where it is not needed and to omit spots which are absolutely essential from the standpoint of plotting. Conversely, a man approaching a control problem from a background of stereoscopic plotting only may dispose the control according to his ideal requirements, but in a manner which is thoroughly impractical from the standpoint of surveying.

Since the ground control is one of the very large factors in the cost of any stereoscopic mapping enterprise, the importance of planning this part of the work by thoroughly qualified personnel cannot be overemphasized.

The difficulties of identifying control are frequently underestimated. It is difficult to impress a client having his own engineering organization with the difficulties of identifying a point on the picture. It seems so easy to take a picture onto the ground and place a needle prick through the image of a control point. This is far from the case.

Within our own organization, personnel with years of experience will seriously misidentify about 5% of the points. Clients who have taken our advice seriously and have attempted to permit us to educate their field men, sometimes bring in as good a record as only one point in ten misidentified, but sometimes their percentage falls to one misidentification out of four.

What then are the difficult factors in this operation which superficially seem so simple? The average man who goes into the field does not have the remotest idea of the sort of thing which the operator of the stereoscopic instrument can see. Of course, if the country is rich in cultural detail, the problem is greatly simplified and even the inexperienced man may succeed with the assignment. In such a case, a fence corner, a point on a building, the corner of intersecting roads, or bushes or trees that can be readily tied to one of these easily identified definite points, afford an easy answer to the problem. When, however, the mapping is in relatively virgin territory, the problem at once becomes most difficult and inexperience becomes a serious handicap. In a region of rolling hills or desert country of a monotonous character, only the exercise of the greatest care will result in success. On the desert one must keep track of his position almost from bush to bush and wash to wash, as otherwise he becomes hopelessly lost. The same is true in rolling hills and any timber covered country.

In any region other than a highly cultured section, the identification engineer must use stereoscopic vision. Many engineers develop the capacity to view the pictures stereoscopically without a stereoscope. If a man cannot do this, he must carry a stereoscope. We have no case on record where a man has ever succeeded in difficult terrain without the aid of stereoscopic vision and we have many cases on record of dismal failure.

Assuming that the engineer confronted with the problem of field identification is competent at actually spotting the station on the picture, he may spoil it all by not writing a proper description. Suppose for example, the station is in clear rolling country on a smooth round knoll. The man doing the locating may put a stick in the ground and intersect this stick from two or three definitely identifiable objects. On his picture he can lay off these angles with a protractor and get a satisfactory position provided the differences in relief are not too great. To the man operating the stereoscopic plotting instrument the prick mark on this rolling knoll means nothing. The knoll looks all the same to him. If, however, the description were to read something like the following, the point would prove useable:

"Highest point on knoll, 80 feet south of saddle, 120 feet from bush 'A,' 260 feet from tree 'B'."

In timbered country, a prick some place in a mass of trees is almost impossible for the machine operator to locate unless it is adequately described, perhaps as follows:

"Tallest tree in vicinity. Top of tree is truly over station at base of tree," or

"Pine tree, only one in group of oaks," or

"Large chestnut tree. Station is eccentric 15 feet north of center of crown of trees."

The man in the field should always remember that the man doing the plotting can see only the top of things. Another common mistake made by people attempting to identify in the field is to confuse an object and its shadow. Oftentimes an engineer will prick what, for example, is supposed to be the north side of a bush, only to find that the point pricked is the edge of the shadow of the bush some distance from the true location. In selecting bushes, it has been found desirable to take the middle of the bush at the ground as the station. If the bush is too big or too irregular in shape to determine its middle, the ground should be selected on the sunny side of the bush.

In describing points which are to be used for stereoscopic plotting, the engineer must be an imaginative fellow with a good vocabulary. The following are distinguishing features which help the man on the machine:

COLOR —compared to surroundings.

DIRECTION—from definitely identifiable points.

DISTANCE —from definitely identifiable points.

HEIGHT —such as highest point or lowest point, or 5 feet lower than highest point, or 8 feet higher than lowest point, or 7 feet below the top of rock.

SHAPE —such as center of round bush, or northeast corner of irregular bush.

DRAINAGE —such as so many feet northeast of a stream intersection.

CULTURE —such as ground at intersection of fences; angle of trail; east end ridge of house, 14 feet above ground; southeast corner roof of house, 20 feet above ground.

The cost represented by a misidentified point is not only the cost of establishing that point and of identifying it which would be the total in case the machine operator could just abandon the point and try to get along without it. If there is one misidentified point in a group of five or six in a stereoscopic model, the operator has no very good way of telling which one of the group is out. He has to try various combinations until he finds out which of the group are consistent and hang together and by this elimination single out the bad point. If the error is large, it is much less serious than if it is very small. A large error can usually be spotted at a glance. An error in identification of only 0.02 or 0.03 inch sometimes takes hours to isolate.

The number of mistakes made in plotting the projection and the control on the sheet are almost unbelievable. Mistakes of this kind are so common that in order to conserve the time of the plotting machine, it has been found desirable to make a practice of having one man plot the points from the co-ordinates and have another man check backwards by determining the co-ordinates from the point and comparing the co-ordinates so determined with the originals. Every kind of double checking which can be employed to conserve the time of the stereoscopic plotting machine will prove economical.

The character of the photographic work in preparing the diapositive plates which are to be used for stereoscopic plotting is an important cost factor. If plates which were not in perfect contact with their film are permitted to get into the files, the plotting machine may be tied up for several hours while this defective plate is being replaced. If a plate of poor photographic quality is passed on to the machine, the operator's stereoscopic vision will be impaired. The desired accuracy of setting suffers and the time required to perfect the stereoscopic model will be greatly increased.

A plotting machine like the stereoplanigraph is a bottle neck through which the entire map must flow. It is therefore essential to plan the stereoplanigraph work insofar as possible so that the most capable operators do the more difficult operations. The competent operator will set up and horizontalize a stereoscopic model in one-quarter of the time required by a man of less experience. On the other hand, this man of less experience will probably be able to draw planimetry just as rapidly as the best operator. It is usually possible to have the work scheduled so that the setting up of new models falls in the shift of the man best qualified. Sometimes it may be necessary for the qualified operator to work an hour or two overtime to perfect a model so that the less experienced man who follows him can start right in to draw.

There is no substitute for experience on the part of the stereoscopic operator. The work should be planned so that the competent operators spend all their time in actual primary plotting. This statement will certainly be protested by some of the current users of the multiplex type of equipment. It is the practice of these operators to first do the primary drawing on the sheet with the machine and then spend the necessary time to smooth and finish it by hand. In an organization which has plenty of plotting equipment, this practice may be tenable although it seems highly inefficient to let a plotting machine stand idle for hours while the operator is doing a job which a topographical draftsman could do just as well. Furthermore, if salary scales are properly balanced in accordance with the laws of supply and demand, a competent stereoscopic operator will be a more expensive man than a competent topographical draftsman. For all these reasons, the operator should be supported by one or more draftsmen who take over the sheet after the primary plotting from the machine, and do the necessary redrafting.

It has been the experience with the stereoplanigraph that it takes two competent topographical draftsmen to keep up with one top notch operator.

So one of the important factors in the cost of stereoscopic plotting is to have operators on the machine who can turn out the maximum amount of map in a given time. The fixed charges of equipment, overhead and salaries should be spread over as many square miles as can be crowded through the machine. One or two more draftsmen per operating unit are less costly than an expensive photogrammetric operator doing drafting with the machine standing idle.

The altitude and scale of photography are, of course, all important in the cost. The more area which can be covered per picture, the less the control, photographic work, flying and setups per square mile. What then are the factors which determine the proper altitude?

In the first place, the system itself has its limitations. There will be optical, mechanical and personal errors limiting the precision which can be achieved under average conditions to a certain percentage of the airplane altitude. Conditions, however, are rarely average. For example, if stereoscopic mapping were to be attempted in desert country, such as exists around El Paso, stereoscopic vision is at its worst and the average system working under these conditions will produce errors perhaps twice as great as they theoretically should be. An important factor of cost is the necessary ability, based on experience, to anticipate the result which can be expected from a certain character of terrain so that the flying height can be planned accordingly.

There is another type of country which works quite the opposite from the above example. In the Grand Canyon type of country, where there are many blind spots in any stereoscopic pair of pictures due to the steepness of the terrain, the average accuracy will probably be improved by flying higher. At the smaller scale secured from a higher flight, more area is within the stereoscopic field of vision at one time and this larger area is conducive to better interpolation through the blind spots. The same logic will apply to steep timber covered country. If this timber country, however, is interspersed with valleys consisting of low rolling smooth hills, as in Tennessee, the higher altitude which might be most effective for drawing the timber will cause a complete breakdown of accuracy on the smooth rolling hills. On these hills, there is small detail which will be picked up at lower altitudes but is not resolved at all at smaller scales. For this reason, stereoscopic vision breaks down. An important factor then in the cost of stereoscopic mapping is this ability to select an optimum flying altitude based on an advance study of the project.

An all important factor in the cost of stereoscopic mapping is the system itself. There are many experienced photogrammetrists who will frankly disagree as to the relative efficiency of the aerocartograph system, multiplex system, the stereoplanigraph system, the Brock & Weymouth system and the many others with which they may be familiar. Most of us will agree that precision plotting is not practical from pictures subtending an angle of greater than 90°. Even in the Tennessee Valley where slopes certainly are not the steepest in the United States, many blind spots add to the difficulty of plotting from 90° pictures. In fact, in the Tennessee Valley, the present stereoplanigraph program was planned with increased strip overlap in recognition of the difficulties of employing a full 90°.

If it were possible to cover enough area per stereoscopic model, no necessity would arise for attempting to carry control forward. To the best of the writer's knowledge, there is to date little, if any, valid experience in the United States tending to prove the economy of bridging any models without control. As a military matter, the advantages of carrying control forward are self-evident. As a civil proposition where precision mapping is the object, there appears little justification excepting in cases of terrain affording unusual difficulties in establishing control on the ground. Since ground control is one of the largest factors of cost in stereoscopic mapping, no satisfactory final answer can be arrived at until the merits of carrying control forward versus controlling every model are settled.

In summary, we may say that the one all important factor resulting in economy in any method of stereoscopic mapping is experience. This experience must extend through every phase of the work from the initial planning to the final publishing.

ERRATA

The following errors in Vol. IV, No. 3 of PHOTOGRAMMETRIC ENGINEERING have come to the attention of the Editor:

The designations in Fig. 1 on page 193 of the wedge spectrograms for Special Panchromatic Aero and Ortho Aero Films are inverted. *A* should be Eastman Ortho Aero Film and *B* should be Eastman Special Panchromatic Aero Film.

Page 203, line 28—13° should be 17°.

Page 204, line 28—unchartered should be uncharted.