THE USES OF HIGH ALTITUDE PHOTOGRAPHY FOR MAPPING AND RECONNAISSANCE*

A Discussion

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MR. DICKERSON'S paper pointed out very clearly that economy is the main reason for high altitude photography in peace-time mapping work. The fact that this procedure may be utilized to materially reduce errors in horizontal position caused by tilt and relief offers attractive possibilities to the regional planner or highway engineer. He is unfamiliar with photogrammetric techniques and hence uses the pictures primarily as a surface inventory. In such a situation, the more nearly the photograph resembles a map, the more satisfactory it will be. For a specific ground area, this condition may be approached by the simple expedient of flying as high as is practicable.

ERRORS IN HORIZONTAL POSITION CAUSED BY RELIEF

The planner is primarily interested in knowing what errors to expect in terms of feet on the ground, rather than of inches on the picture. Accordingly, it is convenient to re-write the usual displacement formula for a truly vertical photograph as

$$D = \frac{Rh}{H} \tag{1}$$

where D is the error in the datum
R is the distance in the datum from the nadir to the point in question
h is the height of the object above datum, and
H is the flying height above datum,
so that the relief displacement may be reduced to any desired amount merely by the expedient of flying high enough.

Much preliminary work is done on $7\frac{1}{2}$ minute Geological Survey sheets, so that the photograph will meet map standards if there is no error in position of more than 50 feet ($0.025'' \times 24{,}000/12''/'$). The curves in the left half of Figure 1 have been prepared from Equation 1 to show the amount of relief that produces an error of 50 feet in horizontal position for points at various distances from the nadir point for four different flying heights. Experience indicates that for much of the work mentioned, a scale of 1:7,200 has proved satisfactory with pictures having a 9×9-inch format. In this situation, the points in the extreme corners are approximately 6.3 inches or 3,800 feet from the nadir (principal point of a vertical). The vertical line drawn this distance from the nadir on the figure permits ready comparison of the permissible relief at various flying heights.

Figure 1 is equally valid for any degree of enlargement, since the curves are plotted in terms of ground distances. Many projects using negatives at a scale of 1:7,200 require six-diameter enlargements in critical areas. If such enlargements are to be as accurate as a map at this scale, the allowable ground error is reduced to 18 feet. The right half of Figure 1 has curves indicating the amount of relief that causes such error at various distances from the nadir point for the same flying heights used in the right half of the figure. From the user's viewpoint, the permissible relief at higher altitudes becomes large enough

* This paper by Lewis A. Dickerson was published in the March 1950 issue, Vol. XVI, No. 1.

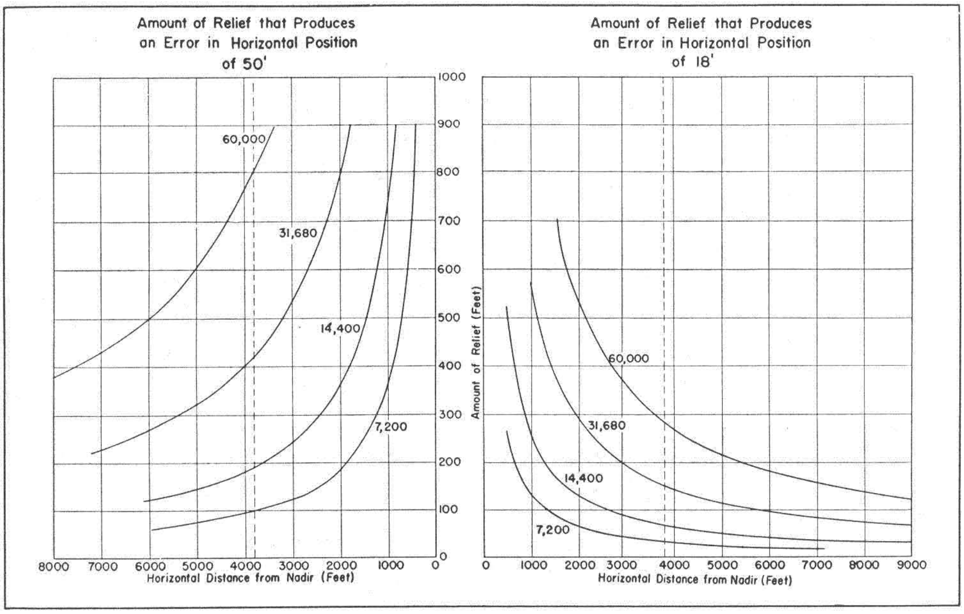

FIG. 1. Curves showing the amount of relief that produces an error in horizontal position of 50 feet (left half) and 18 feet (right half) at various distances from the nadir with varying flying heights.

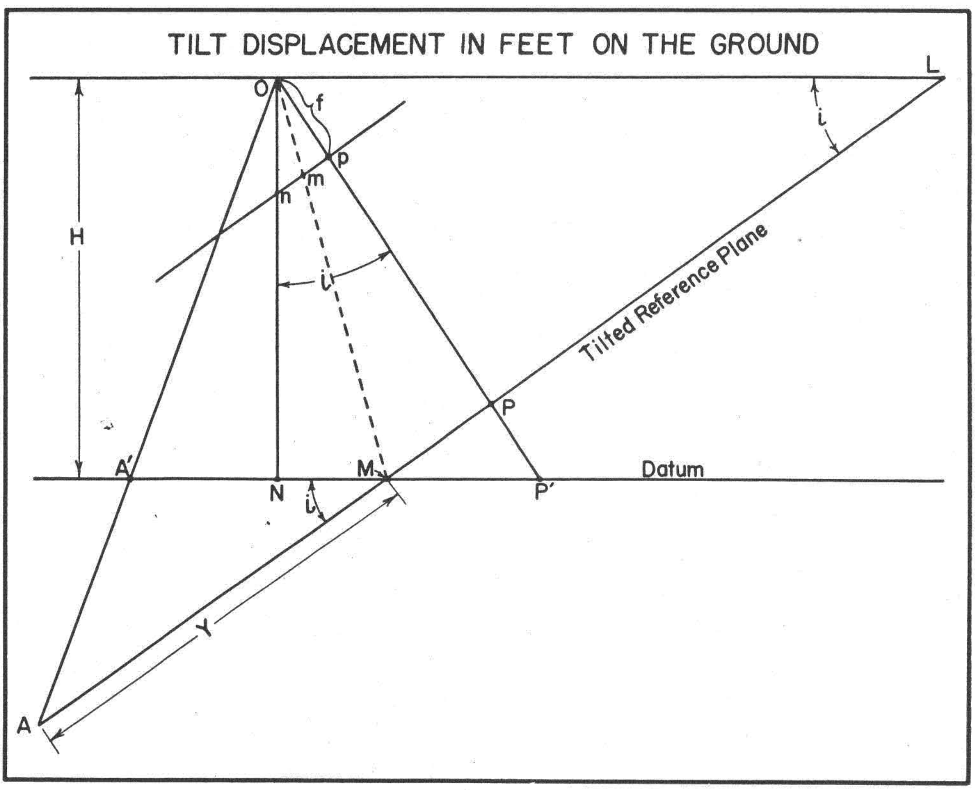

FIG. 2. Errors in horizontal position caused by tilt.

to present attractive possibilities over large sections of the Atlantic seaboard, the Mississippi Valley, and the Plains states.

ERRORS IN HORIZONTAL POSITION CAUSED BY TILT

Errors in horizontal position caused by tilt may be calculated from Figure 2. This shows a photograph taken at O, a height H above the datum, with an angle of tilt i. It is assumed that the ground is level. The diagram is drawn in the principal plane since it is well known that for a given distance from the isocenter, the tilt displacement is a maximum along the principal line. Accordingly this is the worst condition. For convenience, the line AL is drawn through M (the ground position of the isocenter) parallel to the tilted picture, and extended to L where it intersects a horizontal line through the exposure station. This line AL represents the incorrect ground distances that would be obtained by scaling the photograph and considering it a true vertical. Let Y be the erroneous ground distance MA measured in the line AL from the isocenter to point A. Let Y' be the true ground distance MA' measured from the isocenter to the datum position of the point A'. Since triangles LAO and MAA' are similar, then

$$\frac{MA}{LA} = \frac{MA'}{LO}.$$

Let $Y=AM$, and $Y'=A'M$. Now $LA=Y+LM$, and $LM=LO=H$ cosec i. Accordingly

$$\frac{Y}{H \operatorname{cosec} i + Y} = \frac{Y'}{H \operatorname{cosec} i} \quad \text{or} \quad Y = \frac{H \operatorname{cosec} i \cdot Y'}{H \operatorname{cosec} i - Y'}.$$

Let $E=Y-Y'$, where E is the error in the length of the line MA' when measured in the tilted plane, and it will be seen that

$$E = \frac{(Y')^2}{H \operatorname{cosec} i - Y'} \tag{2}$$

where Y' is plus on the down side and minus on the up side. From this, it will be seen that for a given amount of tilt the errors along the principal line (in terms of actual ground measurements) depend on the distance from the ground isocenter and the flying height.

Figure 3 has been prepared from (2) to show the errors in the principal line produced by a tilt of 3° for various distances from the principal point. A minus sign is used to indicate that distances are too short when measured on the up side, and too long when measured on the down. Inspection of the curves will make the advantages of high altitude photography quite evident.

TILT AND RELIEF COMBINED

In practice, there will be errors due to both tilt and relief so that the combined effect must be considered before the photo user can be guaranteed that the total will not exceed a certain specified amount. Since there is no way to predict where the principal line will lie, nor what its position will be in relation to the highest hills, the only procedure is to assume the worst:—that the greatest relief falls on the principal line. Figure 4 was prepared by assuming a tilt of 3° and a maximum elevation difference of 100 meters (328 feet). Relief displacements were computed from the nadir point, tilt displacements from the iso-

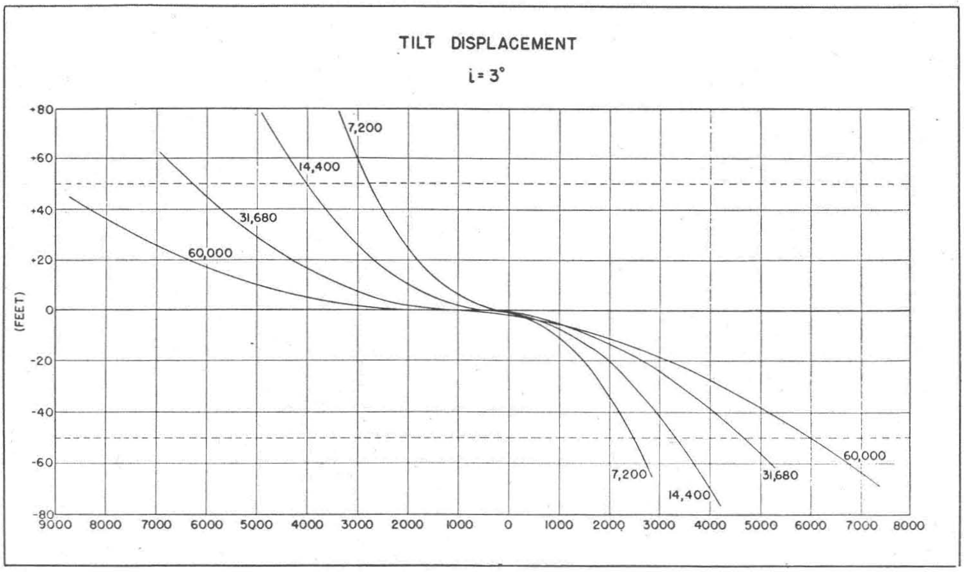

FIG. 3. Curves showing errors in horizontal position caused by a tilt of 3° in photographs taken at various flying heights. The abscissa represents ground distances in feet from the principal point.

center, and the combined errors plotted in terms of the true ground distance from the principal point, since the latter is the only available reference point on the picture. It will be noticed that the total error is worse on the down side, since there both effects are in the same direction. Lines have again been drawn 3,800 feet from the principal point to indicate the error in the extreme corners of a 9×9 picture having a scale of 1:7,200, and it will be noticed that this is only 37 feet in pictures taken at a height of 31,680 feet.

SUGGESTED PROCEDURE

With cameras now in commercial use, the higher altitudes suggested would give negatives at a smaller scale than is desirable for planning work. If the cost of longer lenses seems prohibitive, the work in British Columbia* has pioneered a promising solution to the problem. Here they are able to obtain two-diameter enlargements that have the sharpness and photographic quality of contact prints. This is done by careful design of the aerial camera mount, the use of a precision enlarger that is carefully adjusted, and adoption of the Western Union concentrated-arc light which is virtually a pin point source. Following these ideas and assuming the present 9×9-inch contact prints at a scale of 1:7,200 as satisfactory as to size, scale, and format, the smaller-scale high-altitude negative could be masked off in the enlarger so that the principal point was at the center of a square covering 5,400 feet on the ground. When such a negative was enlarged to 1:7,200, the resulting print would be 9×9 inches and would appear similar to prints with which the customer was already familiar.

The degree of enlargement proposed above is in the order of magnitude of the successful work already referred to in British Columbia. If a 24-inch lens

* Andrews, G. S., "Air Survey and Photogrammetry in British Columbia," PHOTOGRAMMETRIC ENGINEERING, Vol. XIV, No. 1, March 1948, pp. 134–153.

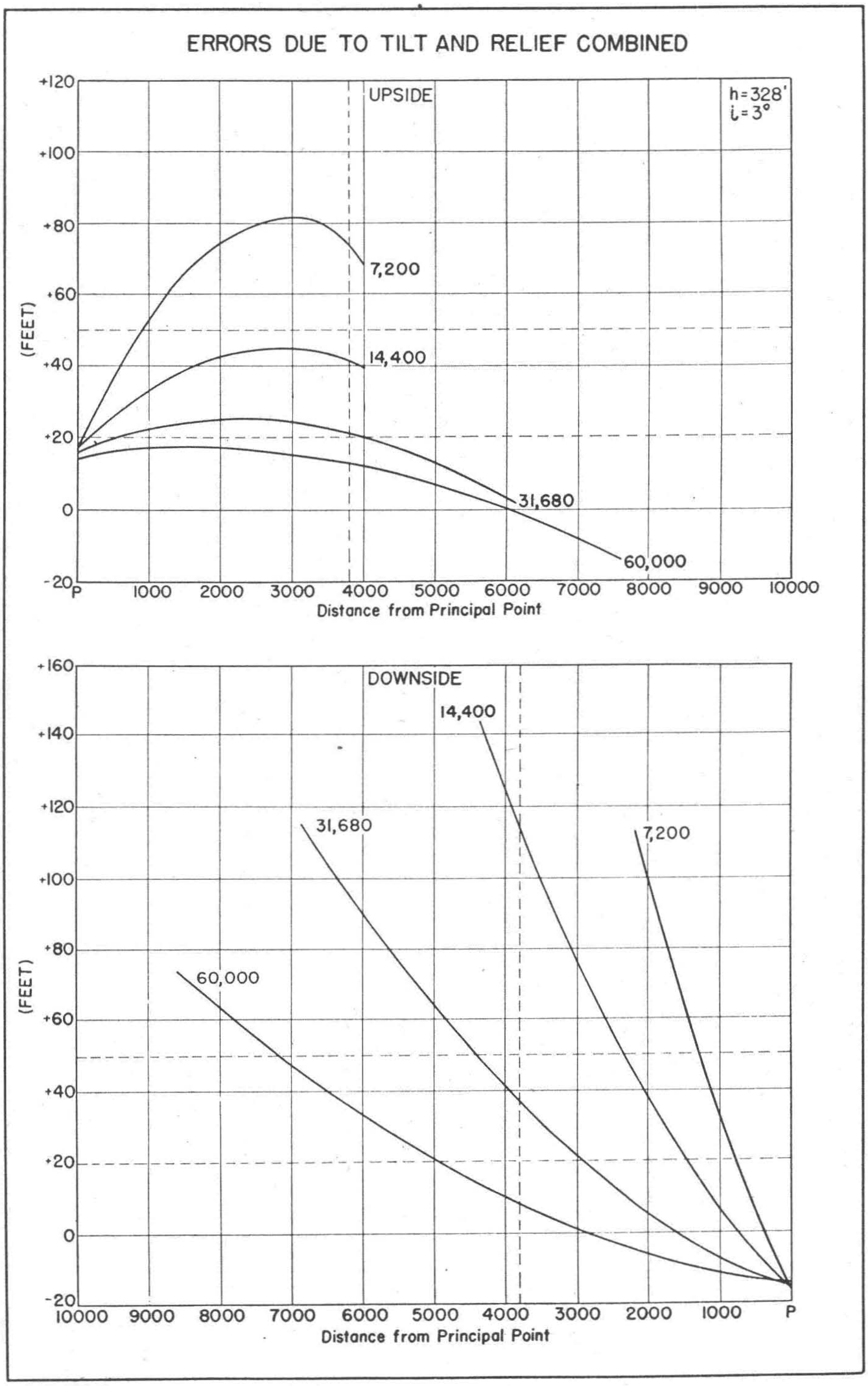

FIG. 4. Errors in horizontal position caused by a tilt of 3° combined with relief of 100 meters (328 feet).

were used at a height of 31,680 feet, the desired 1:7,200 scale would be obtained with a 2.2-diameter enlargement. To get the 1:1,200 scale sometimes required would of course necessitate a 13.2-diameter enlargement. This does not seem an excessive figure to expect from the concentrated arc light since 8- and 10-diameter prints are frequently made with conventional enlargers.

Admittedly it might be extravagant to use a roll of film 9 inches wide if the area used were only 4 or $4\frac{1}{2}$ inches square on the original negative, although the extra coverage might be convenient on some occasions. The alternative would be to use film 5 inches wide in a standard magazine masked the proper size, and with suitable adjustment in the film metering mechanism.

The two main objections to the above procedure arise from the fact that (1) the stereo effect will be reduced, and (2) high altitude photography as suggested in this paper will be more expensive than current procedures because there is no increased coverage to reduce the number of pictures or the number of strips. In numerous cases the decreased stereo effect would be of little significance, since unfortunately many engineers and planners do not know how to use a stereoscope. In regard to cost, that will undoubtedly come down as more work is done at higher altitudes and navigational devices are improved to permit more precise flying. The object of this paper is primarily to point out one distinct advantage in high altitude large-scale photography in the hopes that commercial concerns will test the merits of the scheme by flying as high as is practicable on all large-scale projects.

USES OF AERIAL PHOTOGRAPHS IN FOREST RECREATION*

A DISCUSSION

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WE WHO work in the field of forest recreation are indebted to Robert N. Colwell for his paper, "Uses of Aerial Photographs in Forest Recreation," which appeared in the March, 1950, PHOTOGRAMMETRIC ENGINEERING. It is a valuable and precisely detailed addition to the basic literature of forest recreation.

Not only did Mr. Colwell explore coverages inherent in his descriptive title, but he sensed intangible values within forest recreation which might need clarification or defense in relation to his proposals. This he did by admitting (page 31) that "an enthusiastic attitude has purposely been assumed," and by the editors inviting comments on his paper.

Mr. Colwell's examples and illustrations are valid and commendable. Accordingly little concerning them will be included in this discussion. "Workers in the field of forest recreation," (as Mr. Colwell termed them) are today bedevilled by the task of protecting forest recreation areas against mounting numbers of outdoorsmen, despite funds curtailed by other needs of government. Hence the savings possible through reconnaissance by aerial photography prior to the establishment of recreational facilities, are certainly welcome. Aerial photographs should be used in most forest recreation projects which propose to modify forest recreation areas.

* This paper by Robert N. Colwell was published in the March 1950 issue, Vol. XVI, No. 1.