S. A. Veress*
University of Washington
Seattle, Wash. 98105

Harry P. Jones
H. P. Jones Assoc., Inc.
Bellevue, Wash.

Airport Design Application

Photogrammetric method is considerably more economical than conventional ground surveys.

Abstract: *Photogrammetry is applied to a clear-zone—the zone which aeroplanes use when approaching for landing and taking off from an airport. This zone must be free from any obstruction. Rectified photographs were used to determine the location and the identification of the obstructive object, and its elevation was obtained by a Kelsh-plotter, orienting it to the clear zone. The economical evaluation resulted in a 1:9 ratio favoring the photogrammetric method when compared to ground methods.*

Introduction

Air traffic has increased several fold during the last decade, compared to that of the previous period. This increase, accompanied by a complete utilization of jet transport planes has resulted in an increased capacity and greater air speed. These factors contribute to the inadequate capacity, as far as the runways and passenger handling is concerned, at most of our airports. As a consequence, the airports must expand in order to provide the service demanded by the community in which they are located. The extention of an existing airport, or the establishment of a new airport, is an integrated activity involving the design of terminals capable of handling passengers and cargo, the design of runways, and the study of the clear zone for air traffic control.

Photogrammetry can be used in all of these three phases; however, in this article our remarks are confined to the clear zone.

Problem Definition

The clear zone is composed of three planes forming a geometrical shape like a channel. The basic plane, which is usually referred to as the clear zone slope, begins at about the end of the runway, has a slope of 35:1 to 40:1, and extends usually 10,000 feet along the centerline of the runway. This is illustrated by Figure 1-A, where the clear zone slope begins at 200 feet beyond the runway, has a slope of 40:1 to 5000 feet with a change of slope to 37:1 at this point, and extends another 5000 feet. This clear zone slope is 500 feet wide at the beginning and is 2500 feet wide at the end.

Two so-called transitional surfaces tie to this plane which are represented by Figure 1-B. The transitional surface extends 150 feet in elevation above the elevation of the airport. The top view of this clear zone is given by Figure 1-C where the solid lines represent the outlines of the planes as labeled.

This clear zone is the zone which the aeroplanes use when approaching for landing or taking off from the airport. As a consequence, this zone must be free from any obstruction. Therefore, the basic project is to study the zone and analyze it with respect to (a) the elevations of the objects in this zone, and (b) their horizontal locations. This is indicated by the trees in Figure 1-A. A clear zone study can be divided into two basic phases: firstly, the identification and determination of location of objects, and secondly, the determination of the elevation of objects with respect to these design planes.

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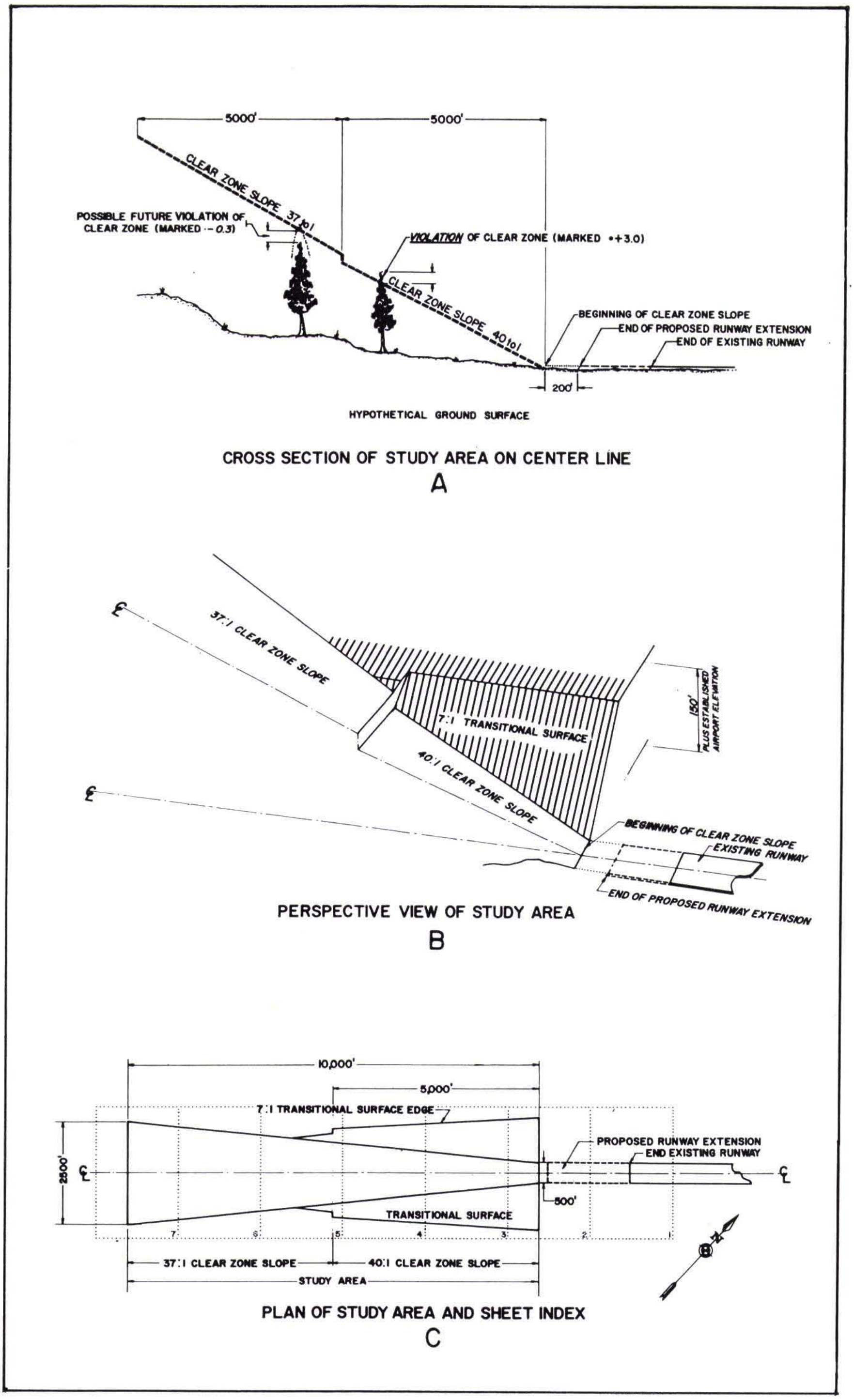

FIG. 1. The clear zone is defined by inclined planes in space oriented with respect to an airport runway

The specifications, as far as the required accuracy is concerned, can be established for these two phases of work. In the first phase, the identification and the location of the object, the emphasis is on identification, so planimetric accuracy can be of a lower order. For example, if the object is a tree which can be identified, the planimetric accuracy does not need to be better than ±15 feet because the point is within the crown of the tree with this specification. The first conclusion can be is that a rectified photograph or photo-map would be ideal for this purpose because the identification on this map is positive and the accuracy of this photo-map can be obtained within the above limit.

The accuracy of the elevation of these objects related to the planes should be greater than that of mention of the planimetry. The required accuracy can be specified as ±1 foot. This accuracy can be obtained photogrammetrically, for example, if one uses Kelsh plotter and the model scale is 1 inch = 100 feet. The accuracy of the elevation read at a point is about the above mentioned value.

The conclusion of this problem analysis is that the clear zone study can be performed photogrammetrically, and the application of photogrammetry has the advantage that the time required for this study is approximately one tenth of the time needed by a conventional ground survey, particularly if large numbers of objects violate the clear zone. The economy is better by an estimated 1:7 to 1:10 ratio.

Photogrammetric Method

The actual photogrammetric process was established by Harry P. Jones Associates, Inc., within the contract by Port of Portland Commission, associated with the extention of Portland International Airport.

The site was studied on a USGS quadrangle map with respect to the relative elevations on the ground and to the required photo-coverage. The elevation of the airport runways is 17 feet above mean sea level and the elevation of the end of the clear zone is about 200 feet above sea level. The area was covered by eight photographs or seven models, (see Figure 1-C) assuming a photograph scale of 1 inch = 500 feet, which was determined by the accuracy requirement for elevations. The maximum relative ground elevation on a single photograph was found to be 60 feet, and in a stereo model, somewhat more than 30 feet.

These data determine the choice of the aerial camera. A camera with 8 1/4-inch focal length would be more suitable for the photomap because the image displacement due to relative elevation of the ground would be considerably smaller than on photographs taken with a camera of 6-inch focal length. However, the base height ratio of 8 1/4-inch photographs is far less favorable than that of 6-inch photographs. Because elevation accuracy which is a function of base-height ratio, is rather important, the area was flown with Zeiss RMK-A-15/23 camera (which has a 6-inch focal length) at a flying height of 3100 feet above sea level. With these data and those of relative ground elevations, the maximum image displacement due to the relief was analyzed, and it was decided that the rectification will be performed by models rather than by photographs in order to reduce this displacement. The maximum image displacement for one-half a photograph (a model) was computed and found to be about ±0.02 inch on the photograph, or ±10 feet on the ground. In this computation, it was assumed that the elevation of the plane of rectification corresponds to the middle elevation of the ground covered by the part of the photograph in question. The maximum value of image displacement, ±0.02 inch, on the photograph corresponds to 0.10 inch on the map after the five-time magnification; this value is considered permissible.

The ground control points were signalized before the flight, and their positions were determined by Electrotape Wild T-2 theodolite measurement, and by leveling.

The photogrammetric process in the Kelsh-plotter began with the usual relative and absolute orientations, utilizing the ground control points. On the first working sheet additional controls, such as fence corners, street intersections, etc., were plotted for rectification. Further, on this sheet an arbitrary coordinate system was selected and all the ground control was determined in this new system. This arbitrary coordinate system was oriented in such a way that the origin of the system coincided with the beginning of the free zone, and the x-axis was identical with the extended center line of the runway, or the center line of the clear zone. By knowing the horizontal position of the ground control in this arbitrary system, the elevations of the ground control were transformed so that the clear zone slope was assumed as the datum plane having zero elevation. The Kelsh-plotter then was reoriented, as far as the absolute orientation is concerned, to this new coordinate system. This resulted in a rotation of the stereo-model around the axis of the be-

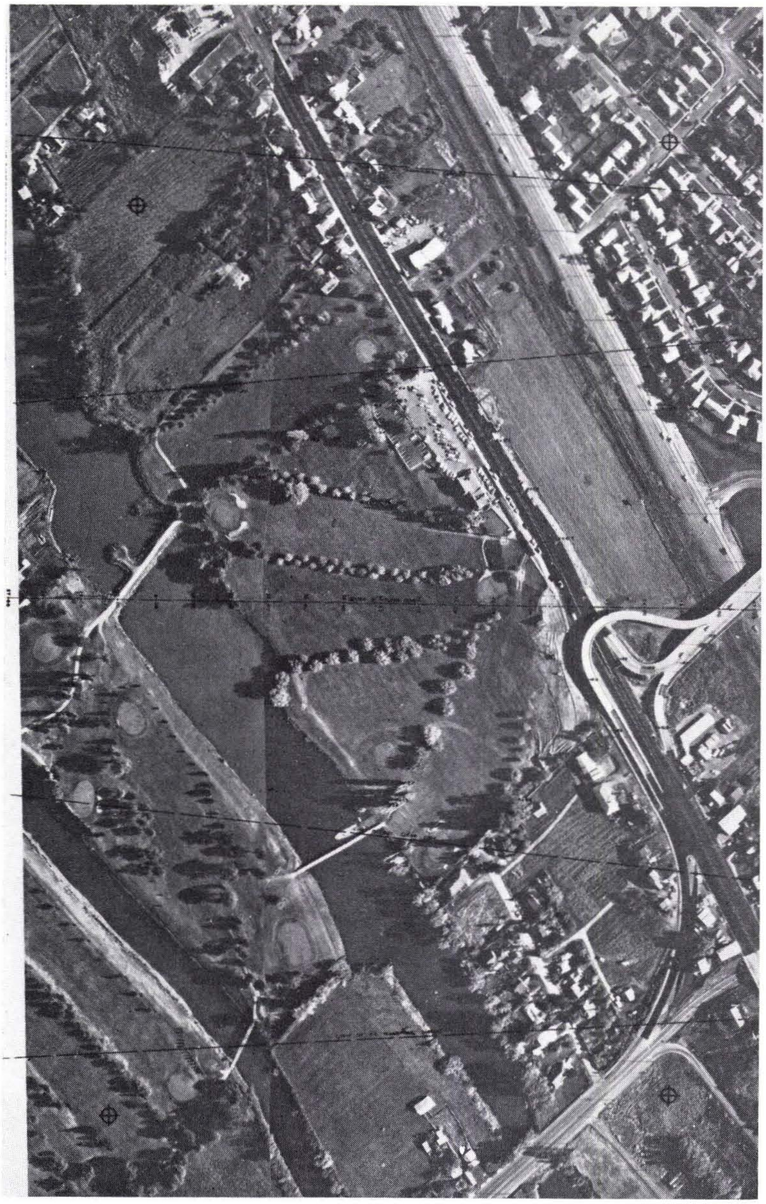

FIG. 2. Rectified photographs overlayed with a work sheet.

ginning of the clear zone and having a slope of 40:1 in negative direction. The stereomodel was scanned, and the elevations of any object with 20 feet under or above the zero elevation was determined. The location of these objects as well as the location of control points were plotted on a new work scribe coat sheet. The working sheet indicated the X-axis of the arbitrary coordinate system as well as the outlines of the clear zone slope and the transitional surfaces.

The work proceeded in accordance with the previously described method to the end of the clear zone. The result of the instrumental process then was two working sheets; one oriented to sea level containing the X-axis of arbitrary coordinate system and the additional controls; the second sheet incorporated the location of ground controls, the X-axis of the arbitrary system, and the location and elevation of the objects that were above or 20 feet below the clear zone slope.

The rectification of the photographs was made from working sheet number 1, finding the best fit to the controls, and the result is given by Figure 2. The rectification was performed on a mylar sheet permitting copies of blueprints or sepias.

The second working sheet underwent a further reduction as far as the elevation of the points is concerned. The elevations of objects determined by the Kelsh-plotter were referred to the elevation of clear zone slope as zero regardless of their locations. Consequently, the elevations of objects located in the area of transitional surfaces needed to be modified so that the transitional surface is at datum, or the zero plane. This modification was performed graphically by constructing a graph to read the elevation difference between the elevation of clear zone slope at an object in question and the elevation of transitional surface at that location. After this reduction of elevations, all the information of the second working sheet was scribed and a copy was made on a transparent sheet of film.

The final result consisted of the sheets of rectified photographs on mylar film, and the second working sheet on transparent film, as an overlay. These two were identified by the location of ground controls, and their correct matching was indicated by crosses at the corners. This final result is given by Figure 2.

Evaluation and Conclusion

The rectified photographs as well as the elevations determined were checked at the completion of the job. It was found that the accuracy was very close to that expected. It was found that on the rectified photographs the maximum deviation in location exceeded the 1/10 inch in some extreme cases. This discrepancy, however, had no effect on the positive identification of the point given by the elevation.

The elevations were correct to the nearest foot for most of the 500 points determined. At some points, such as narrow trees where the top of the crown could not be easily judged by the plotter operator, the discrepancy exceeded ± 1 foot.

Economical evaluation of the work has been performed by comparing the actual man-hours invested during the photogrammetric process to that estimated for a conventional survey. Man-hour requirements were distributed as follows:

Field survey and presignalization	166 hours
Photogrammetric instrument work	56 hours
Rectification, scribing, and copying	96 hours
Total	318 hours

This compares to the 2700 man-hours which was estimated would be required if a conventional survey had been utilized with the same density as the photogrammetric work. As a final conclusion therefore, it can be pointed out that the photogrammetric process is considerably more economical than the conventional survey, and furthermore, the details presented by the photogrammetric method far surpass that obtainable by conventional methods.

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exhibit purposes. The second one was of an emergency set of flood drainage photographs with stereo pairs to determine relative water heights.

Figure 4 indicates the modest tilts of the helicopter plates oriented in a Kelsh Plotter. Table 1 indicates the vertical errors obtained from the 3000-foot altitude.

One particular future job planned by Scott Engineering for helicopter photography is a map at 20 feet per inch of a busy city intersection which includes a cafe parking problem.

We believe that this technique has a future and we are interested in comparing notes with fellow engineers and photogrammetrists on this type of application.

We wish to acknowledge with appreciation, in addition to Messrs. Robinson and Withem for their article in PHOTOGRAMMETRIC ENGINEERING magazine, the creative assistance in making the camera installation of Mr. Vern Bishop, aircraft engineer mechanic at Woodaire, Omaha, Nebr. We also wish to acknowledge the help of Chuck Tingley, Platte Valley Helicopters, Omaha, Nebr.