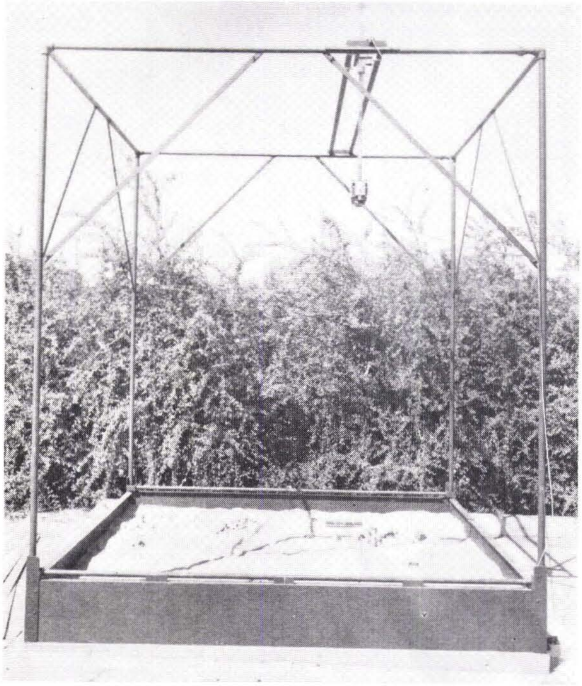

FIG. 1. Terrain model and framework.

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Terrain Model Aerial Photos

College students return to the sand box to experience salient principles of photogrammetric mapping.

(*Abstract on page 1049*)

IN ORDER to stimulate interest and to make the subject more understandable, the author sought to teach a college course in photogrammetry as a laboratory project. The part that seemed to give the student the greatest amount of difficulty was the visualization of flight planning and relation of the focal length of the camera to scale of the finished photograph. To most students the camera was simply a black box that was pointed, triggered, and exposed film to be taken to the drug store for developing and printing. Many of the students had never flown in an airplane and, as a result, had no idea of what they would, or should, see on an aerial photograph.

In order to give a better concept of what the student needs, let me review a little background on the course as taught at Fresno State College. Engr. 103, Photogrammetry, is taught to civil engineering students, not with the idea of making photogrammetrists out of them, but to strengthen their foundation of knowledge about surveying and mapping. With this in mind, it seemed that a project for mapping a given area from start to finish

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offered the best means of attaining this aim. However, obtaining adequate picture coverage with ground control is usually too difficult and expensive.

How to obtain this coverage and make it a complete project from planning stage to a topographic map was solved by simulation in the laboratory. We used a terrain model in a sand box with devices to duplicate aerial photography. Figure 1 shows the frame, model, camera track and boom. In this way the camera can be moved along the track to simulate the flight of the plane. The track can be moved to parallel positions to give properly spaced flight lines. The students are shown the model and given the model scale, which in this case is 1 inch equals 20 feet. The model is 8 by 8 ft., thus covering an area 1920 by 1920 ft.

Each group of three students is given a plotting scale to be used in multiplex compilation and told to compute the flying height of the camera above the average terrain elevation to give this scale. The multiplex has a principal distance of 46 mm. and optimum projection distance of 360 mm. thus giving an enlargement factor of 7.84. The camera has a focal length of 75 mm.

Consider, for example, a plotting scale of 1 in. = 60 ft. The picture scale would then have to be 7.84×60, or 1 in. = 470.4 ft. This would represent $470.4/20 = 23.52$ in. on the model. As the negative is 1.625 in. in direction of flight, it would cover $1.625 \times 23.52 = 38.22$ in. on the model. With 60% overlap, the net progress is 40%, and the picture spacing is $38.22 \times 0.40 = 15.28$ in. In a similar manner the flight spacing can be computed except that the width of the negative is 2.125 in. instead of 1.625. Six pictures are needed in each flight line.

In a similar manner each group of students computes the picture spacing and flight spacing for their plotting scale. Each group sets the camera height and takes its pictures at the proper spacing. The film is then developed in class, contact prints made, and scale measurements checked to verify the results. From the contact prints (Figure 2) the coverage and overlap was checked. During the past semester six groups of students were involved and all came up with the proper answer. The author believes that with this simulated problem the students have a greater interest and incentive to learn these fundamentals and visualize the real problem. They know that their work is easy to check and the competition between groups is rather intense. The students are the severest critics of each other.

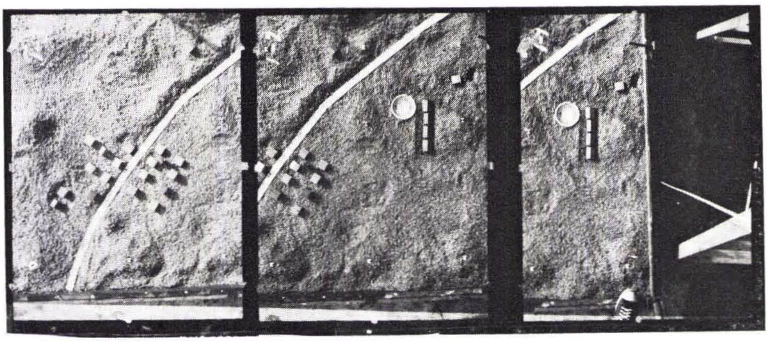
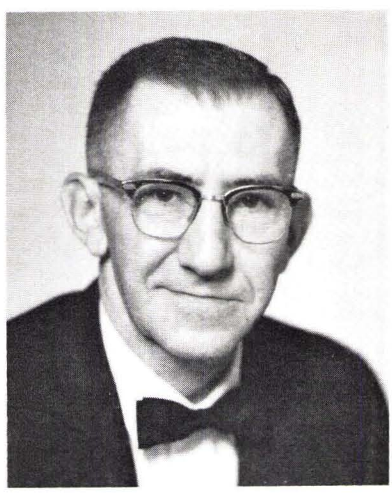


FIG. 2. Contact prints. The original scale was 1 in. = 570 ft. and the flight height was 85.5 in.

For ground control, targets as seen in Figure 3 were sent out on $\frac{3}{4}$-inch square blocks of 3, 4, 5, and 6 inches in height and fastened to the bottom of the sand box. The blocks were



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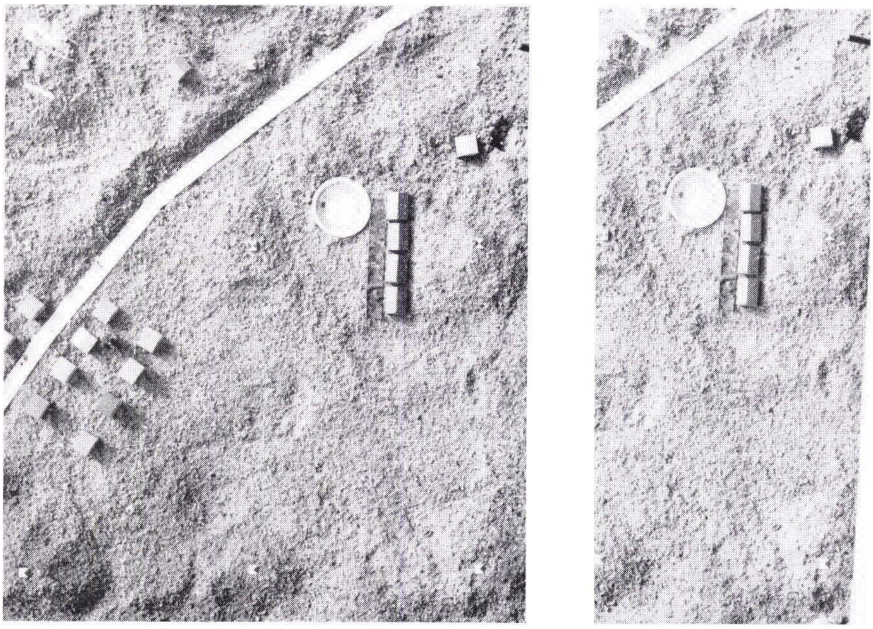

FIG. 3. A stereoscopic pair of photographs of the terrain model. The original scale was 1 in. = 285 ft.

used to eliminate settlement of the sand under the target when a meter stick used for level rod was placed on them. These were arbitrarily set for a flying height of 90 in. and spaced 19 in. apart in direction of flight and on both the right and left side of the picture so that the control was in an ideal position for use as pass points. This arbitrary spacing had its disadvantage in that it was not in proper position for other than the one for which it was set, 1 in. = 75 ft. In searching for another method of anchoring the control points (the present method makes it impossible to change the control points without disturbing the model), we have come up with the answer by using 16-penny spikes cut to desired length and points sharpened. The spikes can be driven into the bottom of the box, the target glued to the head without disturbing the model in any way. In this way the control pattern can be changed for each scale desired.

By orienting the box North and South, one edge can serve as the *Y-Y* (*N-S*)-axis and the other edge as the *X-X* (*E-W*)-axis with one corner as the origin. The ground coordinates can be measured and elevations determined by conventional levels. In addition to the convenience of coordinate axis, by orienting the edges *N-S* and *E-W*, the shadows are in natural position, and more realistic pictures can be obtained.

As an aid in leveling the multiplex model, the left and right pass-point control points were set to the same elevation. In this way the four corner points on each model were the same elevation and leveling in the *X* and *Y* directions was simplified. The instructor has to bear in mind that he is not producing multiplex operators, as each student will probably not have more than four hours of time on the plotter. Anything to speed up the orientation procedure is advantageous. Once the student levels the model and learns the relation of horizontal and vertical scale, and the methods of leveling the model, he can go on to other models that are not set for ideal conditions.

So much for the model and the taking of the pictures. From the negatives the students made enlargements approximately 4× to a 9×7 in. size and determined the scale of the enlargements. From this scale the plotting scale for use with the sketchmaster was determined. Our sketchmasters do not have auxiliary lenses; therefore, the enlargement has to be kept to a minimum so that the distance from picture to map does not become excessive for loss of detail. The plotting scale used was 1 in. = 140 feet.

Next, each student made radial-line templets of each picture using the so-called "spiders." Three of the control points of the model were plotted in position on the projection and the remaining control points (pass points) as well as the principal point of each photo were located by the radial line plot.

The location of the pass points as obtained from the radial line plot was then checked and compared with the known co-ordinates of the points on the model. In this manner the student gains confidence and realizes the reliability of the radial line plot. Where the points do not check out properly, the student also learns that there is no room for carelessness. In this case he repeats the work, but on his own time. The author firmly believes that the student has to find out for himself the tolerances allowed; in other words, the precision necessary for various types of work.

To take advantage of the available equipment and to give the student as much chance as possible to use the various methods of compilation, the map was compiled on four different pieces of equipment. Bearing in mind that each student had ten photos to work, photos 1 and 2 were compiled on the multiplex; 3, 4, and 5 on the sketchmaster; 6, 7, and 8 on the opaque projector; as time permitted the last two, 9 and 10, on the Kail radial line plotter.

We have on hand three different types of Opaque Projectors. One is very similar to a view camera; in fact, we use it as a copy camera. This is used solely to change scale from picture to map. No tilt motion is provided. The second one is a projector with a tilting table utilizing a Johnson head from a plane table. This projector was designed by a student as a Senior Project. By using the tilting table the same effect can be obtained as with a sketchmaster, but much faster as well as allowing greater latitude in scale change. The third is a Map-o-Graph which we have converted to a transform projector. By locating the axis of tilt of each picture and setting it in line with the axis of the tilting mirror, both the mirror and the table can be tilted thus in effect rectifying the print. This adaptation of the Map-o-Graph was also done by a student as a Senior Project.

For the multiplex compilation, the diapositives are made by the students. The negatives, as previously mentioned, are $2\frac{1}{4}\times1\frac{5}{8}$ in., which is the size of the diapositives used by the normal angle projectors. This enables us to make the diapositives by contact printing on the glass plates without using a reduction printer. The first thought that will probably come to your mind will be that by contact printing the horizontal and vertical plotting scales will not be equal, and that distortion will be present in the diapositives as no correction lenses were used. These are legitimate thoughts, but there are good reasons why these were disregarded. The first reason is that we do not have a printer and printers for this size of film are not available. The vertical scale is different from the horizontal scale, but this is of no real consequence as we are not involved in production work where time is of the essence, but in instructional work where the *principle* is more important. The students can see that the scale will be in the ratio of the focal lengths of the camera and projector. In our case the ratio of the vertical to horizontal scale is 75/46 or 1.63. Our tracing table is of the older type with the vertical standard graduated in millimeters; therefore, tables can be built up for vertical settings for any contour elevation at any scale. With this type of table, compilation at any scale is possible without having to worry about the proper set of gears.

As for the presence of distortion, this again is accepted and the student made aware of this, but again you have to bear in mind that student is not a trained operator and he can not perceive small distortions because he will probably have only about four to six hours on the multiplex. All in all we found no apparent distortion that could be perceived and the results of the compilation done by the students was relatively good—actually much better than expected. The relative and absolute orientation of the model were not too difficult as the students seemed to enjoy the work on the multiplex and could visualize the effect of each motion of the projector.

As in the radial line plot, some of the control points were not plotted on the projection

ABSTRACT: *The problems of increasing student interest in photogrammetry and the source of aerial photography for instructional use have plagued photogrammetry instructors since the courses were started. The use of Terrain Model Aerial Photos has been the answer to both problems at Fresno State College. The techniques of making the terrain model and taking the "aerial" photographs are interesting and instructive themselves, in addition to the uses made of the photographs during the course of instruction.*

so as to check their compilation. Again the work was very satisfactory and better than expected.

The compilation of the complete map was done on two different scales, 1 in. = 140 ft. on the sketchmaster and opaque projector, and 1 in. = 60 ft. to 1 in. = 120 ft. on the multiplex. In order to acquaint the students with methods of reproduction of maps and scale change as done commercially, the publication scale of maps was set at 1 in. = 200 ft. The two maps were then photographed on the copy camera (which incidentally was designed and built by a student as a Senior Project) to the common scale of 1 in. = 200 ft. The contact prints of the maps were then mounted on masonite backing, the composite again photographed at 1:1 ratio, and the join lines opaqued out to form one map. From the resulting composite negative the student made a film positive on cronoflex film from which blue line or color separation scribe coat sheets were made.

Time permitting, $8\frac{1}{2} \times 11$ in. sheets of scribe coat were coated with diazo liquid and using the cronoflex film positive three prints of each map were made on the ozalid machine. Each student scribed one color and a composite print in three colors was made, using the washcoat process. The old well-known sun frame was used to make the prints.

In this manner the student was made familiar with the process used to make a complete map. The author believes that in this manner, by starting with the flight planning and finishing with a three color map that has been planned, flown and photographed, compiled and reproduced by the student, gives him an idea of the process and planning that goes into making of a modern map. Though the student may never have to do any of these things, he will know what to ask for when he needs a map made, and not ask for the impossible or ask for precision not compatible with the results needed. The student is given a tool to use if he needs it in later practice. Again please bear in mind that we are attempting to give a prospective civil engineer a tool to work with and not trying to transform him into a photogrammetrist in six easy lessons.