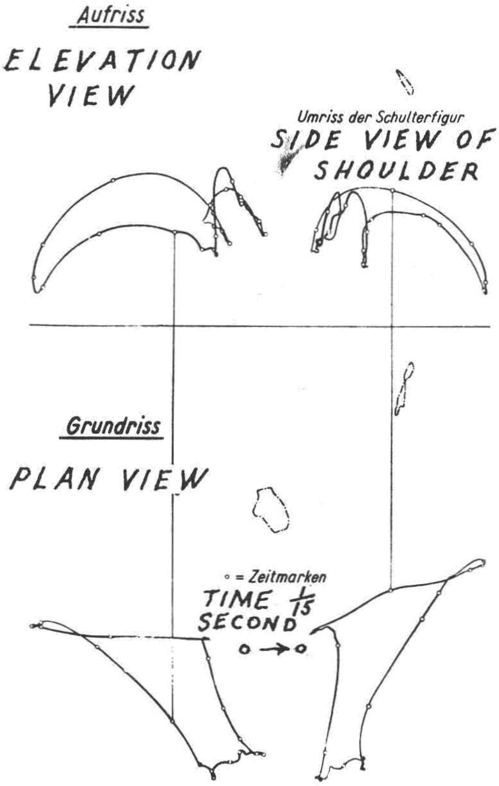

FIG. 9

available at the University, the I. E. class reacted favorably.

One aspect disturbed the class somewhat—that of cost. Like other precision instruments, photogrammetric equipment is very expensive. A combination of the Zeiss SMK stereo-camera and the Terragraph plotter may run to $20,000 or slightly more. However, it remains to be seen if the practicability of the method does not outweigh the disadvantage of initial cost.

There are several alternatives by which equipment cost to the industrial firm might be reduced or even removed as a major disadvantage in photogrammetric motion study:

1. Motion studies could be made on a consulting basis. The consulting engineer would come into a plant which desires a motion study, take the pictures, reduce the raw data on his own plotter, and furnish the plant with the results for the analysis. In this system no equipment cost is involved.
2. A plotting center could be established, to which any firm could send data in the form of pictures. Plotting would be done at the center; thus, equipment cost is lessened by the price of the plotter, or 75 per cent.
3. The method would still be useful if no plotting at all were done. Many motion studies are not concerned with a quantitative analysis. A qualitative analysis would be greatly improved by the mere addition of the third dimension. Viewing could be done on a simple stereoscope of negligible price.

The only way to determining the usefulness of the method is to work with it—to conduct research wherever facilities permit. Research is the very backbone of engineering and may someday prove photogrammetry to be a useful tool in the industrial world.

*Ultra-Wide-Angle Mapping**

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(Abstract is on next page)

NOMENCLATURE for angular coverage of mapping camera lenses has been backed into a corner from which there appears to be no escape. The photogrammetric world is stymied. Some old timers are still around who mapped with normal-angle photography when wide-angle lenses first became available. Now ultra-wide-angle has been added to the group. However, normal-angle photography is not normal, and wide-angle is not

* Presented at the 28th Annual Meeting of the Society, The Shoreham Hotel, Washington, D. C., March 14–17, 1962.

very wide, so photogrammetrists ponder what the next advance in angular coverage will be called.

It has been known for some time that the Russians have been using a mapping system involving photographic coverage on the order of about 120 degrees. Thus, when ultra-wide (or super-wide) angle equipment became available, the U. S. Army Engineer Geodesy, Intelligence and Mapping Research and Development Agency, (GIMRADA) took immediate steps to institute a test program for evaluation of its potential for mapping. Specifically, a Wild A-9 Autograph and a U3-A diapositive printer were procured, and arrangements were made for photography from several agencies that had obtained RC-9 Super-Aviogon cameras. These included Aero Service Corporation, U. S. Geological Survey, and the Air Force.

J. W. HALBROOK

ABSTRACT: *Area coverages of ultra-wide (or super-wide) angle and regular wide-angle photography are compared, and tests with a Wild A-9 Autograph are described. Test results indicate that ultra-wide-angle photography covers about twice the area of regular wide-angle photography when flown for the same vertical accuracy. It is concluded that there are vast areas in the world that are not too rough to be mapped by this new tool of photogrammetry.*

When the angular coverage of a camera is extended to 120 degrees, either the format size or focal-length (or both) has to be different from those of our conventional 6-inch cameras. In the RC-9, the 9- by 9-inch format is maintained while the focal-length is shortened to a nominal 88 millimeters, or about $3\frac{1}{2}$ inches. The proportion, therefore, of the scale of ultra-wide-angle photography to that of standard photography, when the two are flown at the same altitude, is $3\frac{1}{2}$ to 6.

It is generally agreed that the most important characteristic of ultra-wide-angle photography is the extra ground coverage per picture at a given flight height. At equal heights the length and breadth of each photo will be about 1.7 times that of a standard 6-inch photo, or nearly 3 times the total area. Thus when photo coverage alone is desired, only a little more than one-third as many photos are required, depending somewhat on the shape and size of the area being photographed.

Advance information concerning the RC-9 camera indicated that the Super-Aviogon lens was going to be nominally free of distortion. The actual cameras, however, had radial distortions with an approximate 50-micron maximum, including the effects of an aspheric film locator back. With an 88-millimeter focal-length, this compares in magnitude to about 85 microns for a 6-inch camera. Obviously, such an amount could not be ignored, and, since the A-9 Autograph is distortion free, a corrector plate was ordered for the diapositive printer. The aspheric surface of the plate was designed for the average distortion characteristics of several RC-9 cameras on which calibration data was available.

After the A-9 was set up and calibrated at Fort Belvoir, initial tests were aimed at determining, through the use of grids, the internal precision of the instrument itself. These consisted of monocular measurements of X and Y positions of grid intersections for each individual projector, followed by stereoscopic observation and measurement of the flatness of grid models. The plates utilized for this purpose were furnished with the instrument. The grid spacing was such that, when the principal distance was set at 44 millimeters, the base-height ratio was 1.13. Three base-in and three base-out settings were made with a projection distance of 88 millimeters. This configuration most closely represents that to be expected when using RC-9 photography reduced to half-sized diapositives. One setting each, base-in and base-out, was made with the principal distance altered

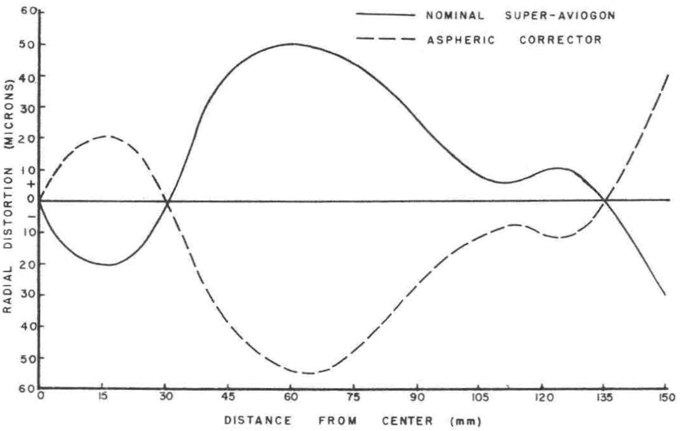

FIG. 1. Calibrated Super-Aviogon radial distortion and corresponding printer compensation.

slightly to yield a base-height ratio of 1.0. This is approximately the base-height ratio obtained when a nominal 60% overlap occurs.

In each case, the grid models were oriented in the plotter and leveled as closely as practicable. Elevation readings were taken at 66 grid intersections. A mean plane was passed through these elevations for each model, and the standard deviation of the departures from that plane computed. The eight standard deviations ranged from 5 to 8 microns, averaging 7 microns or 1/12,600 of the projection distance.

Prior to preparation of any diapositives, the reduction printer was tested to determine, primarily, whether or not the aspheric plate that had been procured for the purpose was correcting the distortion within tolerable limits. The test plates were made at a reduction of one-half to provide the size accepted in the A-9 Autograph. After calibration (Figure 1), it was found that the printer correction was equal and opposite to the camera distortion to the extent that the maximum residual distortion was only about 5 microns at the scale of the camera. Thus, it was considered that the printer error was smaller than the spread of distortion characteristics from camera to camera, and that the printer-instrument combination would contribute a very small error when plotting with photography.

The photography utilized for the terrain model flatness test was all obtained over the Arizona Test Area, some at 10,000 feet and some at an altitude of 20,000 feet above the ground. Two models of the 10,000-foot photography and one of the higher altitude were each set up base-in and base-out by three different operators. The model scale for the low altitude photos was 1:30,000, and the other model was 1:60,000, or nearly the scales of the photography itself.

The Arizona Test Area is covered with a control network, the points being generally located near section corners and therefore are spaced at one-mile intervals. The models from the 10,000-foot photography contained 15 check points and the one from 20,000-foot photography had 54 points.

As in the case of the grid models, the terrain models were leveled as closely as practicable, but with stress laid on removal of visible Y-parallax rather than perfect absolute orientation. The elevations of all points were read and recorded, corrections made for earth curvature, and the departures from the true values computed. A mean plane was passed through these errors and the standard deviation for each model was calculated. Converted to a common scale of 1:30,000, the standard deviations ranged from 1.23 to 1.60 feet and averaged 1.41 feet. Given as a representative fraction, this is about 1/7100 of the flight height.

When the use of ultra-wide-angle photography was first considered, enhanced vertical accuracy appeared possible from the improved strength of figure provided by the larger base-height ratio. On the other hand, it was expected that shortening the focal-length might decrease the scale sufficiently that accuracy would be adversely affected. Actually, both of these occurred but, like the man who put vitamin pills in his gin so he could build himself up while he tore himself down, the results indicate that the gain from improved geometry was more than offset by the loss from the reduced scale.

A fair comparison is afforded between the results from the A-9 Autograph and those normally expected from an A-7. Both are built by the same company, both operate on the same mechanical principle, and the grid tests indicate that the precision of the A-9 tested is about equivalent to that of the A-7 Autograph. Judging from results over several years from the A-7 at GIMRADA and others owned by private companies under contract, and from the results with the A-9 in these tests, the vertical accuracy of ultra-wide angle models is about $\frac{5}{6}$ that of standard mapping photography.

Since the accuracy of a given system is considered to be essentially a straight-line function of altitude, it follows that accuracy equal to that of standard photography could be achieved by flying ultra-wide-angle photography at $\frac{5}{6}$ the altitude. This, then, would reduce the coverage advantage so that the area per photo would be only a little more than double that of regular photography. Still, cutting in half the number of pictures required for a given area seems to be a worthwhile achievement.

Considerable discussion has centered around the fact that in rough terrain there may be hidden areas caused by the low slope of rays from those areas. This is true, of course, but the problem is not limited to ultra-wide-angle photography. There will be hidden areas wherever the slope of the ground is away from the camera station and is steeper than the rays to the camera. This condition is currently plaguing those trying to map rough areas such as the Rocky Mountains, and would be worse if ultra-wide-angle photography were being used. The conclusions are that there are vast areas in the world that are not too rough to be mapped by ultra-wide-angle photography, that it is not to be expected that it will completely supplant regular mapping, but that there will be sufficient advantage in its coverage aspects to insure its widespread acceptance as an important new tool of photogrammetry.

*An Approach to Automatic Photographic Interpretation**

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ABSTRACT: *This paper describes an approach to the automatic identification of the images of targets on aerial photographs. The approach described involves the extraction from the photographic image of two basic types of information, one of them relating to the presence in the image of figures having given shapes and sizes, and the other to the "textural" nature of the image.*

TARGET RECOGNITION CRITERIA

A MAJOR aim of photographic interpretation is the recognition of the presence or absence of given types of features ("targets," in the military case) on given aerial photographs. To perform photographic interpretation automatically, the photographs must be accepted as inputs by the data handling system which will make the recognition decisions. A major obstacle to effective automatic photographic interpretation is the wealth of information, measurable in the billions of bits, which a high quality photograph contains. The human interpreter certainly does not consciously process all of this information in making flash recognition decisions; for recognition purposes, most of the information content of the photograph is redundant. It seems reasonable to conclude that a practical method of automatic target recognition will have to markedly reduce the amount of redundant information contained in the photograph. The result of such a reduction in information may be thought of as a simplified description

* This paper was presented at the 1962 National Convention on Military Electronics.