Photogrammetric Engineering

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FUTURE POSSIBILITIES IN AERIAL PHOTOGRAPHY[1]

IN choosing this topic I do not for a moment wish to convey the impression that I am ignorant of the problems that remain to be solved in order to put photogrammetry on a satisfactory basis according to present knowledge and the present state of equipment development. Such problems exist and they are serious but they are administrative and executive rather than fundamental. The conditions to be met by equipment in order to accomplish what is expected of photogrammetry are fairly well defined and such equipment can be obtained although little of it is in use, a condition that time will remedy.

Nor do I wish to undertake to outline all the future possibilities in aerial photography for I have neither sufficient imagination nor enough time. I shall confine my remarks to two subjects that perhaps have not received enough attention.

Some day it will probably be more generally recognized that the characteristics of an aerial photograph best adapted to giving information of one kind are by no means necessarily best suited to giving other kinds of information. While this may be known to this Society it is hoped that it may receive wider recognition.

Some of the factors significant in influencing the suitability of a negative for a given purpose are: (a) the time of year and the time of day that the picture is taken; (b) the altitude of the flight; (c) the characteristics of the lens such as focal length, angular covering power, definition, and freedom from distortion; (d) the characteristics of the camera; and (e) the characteristics of the photographic emulsions used.

Lens, camera, and emulsion are intimately related so that the usefulness of any photograph is a product of all three but each can be considered separately, of course, as is proved by the fact that in this country they are for the most part made by separate concerns. Co-operation between lens and camera maker has been rather good and the emulsion makers appear to have spared no effort to supply film that approaches as closely as possible to the ideal. All three items fall considerably short of ideal, however, and it is in part to improvement therein that we must look for further advances in photogrammetry.

When one thinks of advances in lens design he usually thinks of improvements in performance for a given focal length such as greater angular covering power, better definition and resolving power, greater speed, etc. Advances in these directions may well be made but perhaps we could make an advance in the use of what we have in this direction by a better choice of focal length.

Certainly one of the fundamental requirements of a photograph relates to the size of the smallest detail that can be distinguished in it. To a certain extent this depends on focal length but it is by no means a simple inverse proportion as might be expected. If the resolving power of a photographic lens depended solely on its aperture as does that of a good telescope objective, then the case for long focal lengths would be undebatable assuming that relative aperture

[1] Paper delivered at the semi-annual meeting of the American Society of Photogrammetry in New York City on September 8, 1938 by Dr. W. B. Rayton of Bausch and Lomb Optical Company.

could be maintained regardless of focal length. In the photographic objective, however, resolving power over most of the angular field is limited by aberrations that the designer has not been able to eliminate. These aberrations are strictly proportional to focal length, twice as large in a lens of six inches focus as in a lens of three inches focus so the minimum circle of confusion that constitutes the image of a point in the object is twice as large in a 6 inch lens as in a 3 inch of the same type. If resolving power be expressed in terms of lines per millimeter it is reasonable to suppose that the resolving power of a 3 inch lens will be twice that of a 6 inch. If the 6 inch lens shows a resolution of 25 lines per millimeter, a 3 inch will resolve in the neighborhood of 50 lines per millimeter. For any given altitude two objects can be found on the ground that are separated by just such a distance that their images are separated by 1/25 mm. which we will assume, for the purpose of the illustration, to be the limit of resolution of the 6 inch lens. If the 3 inch lens is substituted, the images of the same two points will be separated only half as far as before, but since the resolving power expressed in lines per millimeter is twice as great, the same two points will still be separated in the image. Whether they will appear in the photograph will depend on the resolving power of the emulsion.

The resolving power of the negative materials used in aerial photography will average about 45 lines per millimeter. The resolving power of the 6 inch Metrogon lens differs in various parts of the field. At the center it will exceed the resolving power of the plate but at 15° from the center it begins to fall. At any field angle other than zero there will be a difference in resolving power according to the orientation of the lines in question with reference to a radius of the field, the greatest difference existing between lines that are radial and lines perpendicular to them or tangential lines. For tangential lines the resolving power drops to 20 lines per millimeter which is only half the resolving power of the film. Focal length could be reduced to 3 inches and resolving power increased to twice the value of the 6 inch lens before the resolution of the film would be reached.

Such a move would, of course, sacrifice some of the detail now obtainable in the central part of the picture but should entail no loss in other parts of the field wherein existing definition and resolving power are adequate for the purpose.

Furthermore, other emulsions are available that have higher resolving power—up to 75 lines per millimeter or more, and progress is still being made by the film makers so that it may soon be possible to get more detail in a negative with a 3 inch lens even in the center of the picture than is now obtainable with a 6 inch lens.

The resulting reduction in size and weight and cost of cameras and in the cost of film should be ample compensation for the cost of a thorough study of this possibility.

In the above I have been thinking of general aerial photography for practically any purpose. For application to use with Multiplex stereo projectors the reasoning is all the more secure in that the original negative is reduced about four times before projection, using a plate for the positive that has less than twice the resolving power of the negative. In this process it is evident that there must be a 50% loss of detail. If this is acceptable why not take advantage of it in making the negative? But I have argued that with careful photography a 3 inch lens can be made to give as much detail as a 6 inch and do it on a negative half as large. Such a negative would only have to be reduced twice for Multiplex projection and since the positive emulsion has nearly twice the resolu-

tion of the negative there should be practically no loss of detail due to the reduction. This would appear to lead to twice as much possible detail in the stereoscopic model projected by the Multiplex at much less cost in the equipment and supplies required for the photography.

By flying at the same altitude the same angular relations would be maintained, the same stereoscopic parallax would be obtained and the projected stereoscopic model would be of the same scale. The detail should be better resolved.

One other possibility seems to be worthy of some consideration. I refer to photography in natural color. I know the subject has received some study, perhaps much more than I know of, but I do not recall any mention of it before this Society.

Natural color photography is possible through any one of several processes. Some of these require a single exposure through a single lens on a single film, processes in which the filtering is done in the film itself. Others employ two or three plates and a single lens, the light being divided by reflection between the lens and the plates by semi-transparent reflectors. These are also single lens, single exposure cameras. After processing, the three plates are superposed in register and a transparency in natural color results. I would regard multiple lens cameras as inadvisable and any multiple exposure method as impossible.

The multiple plate cameras are, of course, more complex than the ordinary single plate, black and white cameras, and the processing in the darkroom much more elaborate and laborious than the handling of ordinary negatives and prints.

The lens used should meet the ordinary requirements now imposed on it and in addition should be carefully designed so as to form images of equal size for light of as many wave lengths as possible. It would be desirable also that it form those images at the same distance from the lens but this condition cannot be met simultaneously with equality of size, and the latter is the more important of the two in color photography.

In operation, it is highly important that exposure be correct as anyone can testify who has tried it. This leads to the conclusion that it probably could be applied only with great difficulty in wide angle cameras for with wide angle lenses there is always a great reduction in illumination in passing from center to margin of the image. Attempts should be confined to moderate angles, therefore, if disappointment is to be escaped. Otherwise it seems as though the exposure problem might be easier in aerial photography than is the job usually undertaken by the amateur photographer who attempts pictures of all kinds of subjects under all kinds of illumination.

The principal value to be expected from natural color photography would, of course, lie in promoting ability to identify material appearing in the picture. The differences in density in a black and white negative or print are of vastly less value in identification than are the original colors. For the purposes of the A. A. A. for example, it would seem as though the natural color photograph would be infinitely more valuable than a black and white. For mapping, where precise reproduction of dimensions is the fundamental requirement, color would be much more difficult to obtain and much less valuable as a contribution to the work in hand.

It would seem, therefore, not unlikely that he would find it decidedly worth the effort if some enterprising aerial photographer undertook to perfect himself in the making of natural color photographs from the air.