Photography Brief

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Consequences of Enlarging 35-mm Aerial Photography

Enlarging results in changes in focal length, lens distortion, and orientation, and reduces image content.

The use of off-the-shelf 35-mm photography equipment for aerial reconnaissance is gaining popularity because of its simplicity and economy. The film is inexpensive to purchase, and as a result of its small format and the efficiency with which commercial processors operate, the developing and printing costs are low. Unfortunately, the size of the film and the procedures implemented to make commercial printing efficient also create problems in the use of 35-mm photography for remote sensing and photogrammetric applications.

Because slides or contact prints are only 24 mm by 36 mm in size, the film is rarely used without first being enlarged by projection or by commercial printing to one of five standard print sizes. Unfortunately, the enlargement process changes many of the basic photogrammetric properties of the original image. Knowledge of the types of changes that occur, as well as their magnitude, is necessary if 35-mm aerial photography is to be fully and properly utilized, especially for quantitative applications.

The basic information on the enlargement process presented in Table 1 was provided by the Eastman Kodak Company, whose help is gratefully acknowledged. If enlarging is performed by another commercial film processor, the specifics may be different, but the concepts remain unchanged and the information in Table 1 can serve as an approximation.

The most conspicuous consequence of enlarging 35-mm film is a change in photo scale. The scale of an enlarged 35-mm aerial photograph can be found by multiplying the scale of the original negative by the appropriate enlargement factor. In commercial printing, each print size has a unique enlargement factor. The five most frequently requested print sizes and their corresponding enlargement factors are included in Table 1.

Enlarging the film not only changes the scale of the image, but in effect it also changes the focal length of the lens used in taking the photograph. The focal length is increased in direct proportion to the enlargement factor.

A third result of having 35-mm film enlarged in commercial printing operations is that a portion of the image gets eliminated (cropped) from the print. Two factors account for this reduction in image content. First, the film aperture in an enlarger is smaller than the size of exposed 35-mm film. This permits high speed production printing to proceed without requiring each negative be precisely centered in the film holder. Table 1 gives the dimensions of the film aperture used in producing each print size. The second reason for the reduction in image content is a technique known as spillover. It eliminates edge problems on the prints by requiring the dimensions of the projected image to be slightly larger than those of the paper onto which it is printed. A 3.84× enlargement, for example, produces an image 3.598 by 5.280 inches, but the photographic paper is only 3.5 by 5.0 inches. The 0.098 by 0.280 inch spillover allowance can be translated into a film format reduction of 0.648 mm by 1.852 mm. In effect, the effective film format (Table 1), which is the size of the format that actually gets printed, is even smaller than the film aperture in the enlarger. The amount of image lost as a result of the cropping can be as much as 22 percent in 8 by 10 inch enlargements or as little as 9.9 percent in 4 by 6 inch and 8 by 12 inch enlargements (Table 1). Image loss of this magnitude could be an important consideration in flight and project planning with 35-mm aerial photography. Not only might additional exposures be required to obtain proper coverage, but corresponding principal points may get cropped off the print, making determination of the

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TABLE 1. INFORMATION ON THE ENLARGEMENT PROCESS FOR THE FIVE STANDARD PRINT SIZES.

Print Size (inches)	3.5 by 5	4 by 6	5 by 7	8 by 10	8 by 12
Enlargement Factor*	3.84	4.40	5.44	8.64	8.80
Standard Film Format (mm)	24.409 by 36.398	24.409 by 36.398	24.409 by 36.398	24.409 by 36.398	24.409 by 36.398
Enlarger's Film Aperture* (mm)	23.799 by 34.925	23.799 by 34.925	23.799 by 34.925	23.799 by 29.667	23.799 by 34.925
Effective Film Format* (mm)	23.151 by 33.073	23.106 by 34.636	23.379 by 32.684	23.520 by 29.399	23.092 by 34.636
Image Area Lost in Printing (%)	13.82	9.92	13.99	22.17	9.97

* Information supplied by the Eastman Kodak Company

air base difficult if not impossible. Cropping also makes it difficult to locate the principal point of enlarged 35-mm aerial photographs. The principal point cannot reliably be found at the intersection of the diagonals that connect the corners of a photograph because the film is rarely centered in the film holder. As a result, fiducial marks must be present and they must extend beyond the portion of the film's perimeter that gets cropped.

Another consequence of enlarging 35-mm aerial photography occurs with the location of image points. A camera lens not only imparts distortion to the position of image rays that become recorded on the film, but when these rays pass through the lens system of an enlarger, additional distortion is imparted to their location. This distortion may compensate or exaggerate the distortion already imposed by the camera lens. Consequently, not only must the camera lens be calibrated, but the enlarger must also be calibrated if the errors introduced by these systems are to be incorporated into a solution of the photogrammetric problem. To complicate these calibrations, the distortion of image rays in the print is magnified in direct proportion to the enlargement factor.

Finally, enlarging 35-mm aerial film may change the tip and tilt orientation imparted to the original image if the plane of the film and the plane of the photographic paper onto which the enlarged image is projected are not parallel.

In summary, 35-mm film must be enlarged unless users employ microscopic techniques. In addition to changing the scale of the image and the apparent focal length of the camera lens, enlarging can reduce image content, change the distortion curve imposed by the camera lens, and may change the tip and tilt orientation of the original image. Recognition of these complications and consideration of their implications will alleviate many unexpected problems that could otherwise occur with the use of 35-mm aerial photography.

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Errata

In the article, "Shadowless or Sunlit Photos for Forest Disease Detection," by B. J. Myers, M. L. Benson, I. E. Craig, J. F. Wear, and P. W. West, which appeared on pages 63-72 of the January 1984 issue of *PE&RS*, color Plates 1(a) and 1(b) were inadvertantly switched. Thus, photo (a) is shadowless and photo (b) is sunlit.

The review of the book, *Textbook of Photogrammetry* by K. K. Rampal, which appeared on page 575 of the May 1984 issue of *PE&RS*, was prepared using a pre-publication copy which was missing several pages. The published version, which costs $6.50 hardbound, is complete.