type A control. Stereocompilers preferences are given in Table 1. All diapositive plates were Class I medium contrast and were developed in DK60a for 5 minutes at 68°F.

Table 1 gives the combined results of the stereoscopic measurements, and stereocompilers' opinions for the four model sets. The standard deviations are: *Control-type* A—1/12,670, *Control-type* B—1/14,360 and *No control* 1/11,140. Forty-nine stereocompilers expressed first preferences for type A and 50 for type B control; 99 preferences for a contrast-controlled model and 21 preferences for no control.

Conclusions

It can be stated that contrast-control in diapositive printing improves the accuracy of stereoscopic pointings. The percentage of improvement obtained is directly related to the density range of the aerial negative. The negatives used in the research reported herein were not extreme or unusual examples, but were those which might normally be encountered in mapping operations. The percentage of improvement for the contrast-controlled models therefore is not nearly as great as would have been obtained with extreme density conditions of the type that would exist in negatives of snow scenes or rugged mountain terrain.

V. S. Milner and M. N. Tsygano[3] of the USSR recently reported on the improvement of accuracy of stereoscopic measurement using the unsharp-mask technique. The areas chosen for study and the points used for measurement were extreme and, therefore, the results are not directly comparable to those of this study. It is interesting to note, however, that their results are similar to those reported in this paper. They reported an increase in the accuracy of stereoscopic measurements of from $1\frac{1}{2}$ to 2 times (34 to 50 per cent). Note in Table I that in model set four, type B control showed a 40 per cent improvement over no control.

It is hoped that this study may benefit others by furnishing quantitative data in an area where pictorial quality is often the only guide.

[3] Experiments in the Use of the Unsharp-Mask Method of Preparing Contact Prints and Diapositives: Geodesy and Cartography, Nos. 3 and 4, USSR Ministry of Internal Affairs.

*Autofocus Rectifier Modified for Electronic Dodging and Automatic Exposure Control**

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(*Abstract is on next page*)

This paper discusses the basic construction and operational principles of a Bausch & Lomb Autofocus Rectifier that has been modified to provide electronic dodging and automatic exposure control. The rectifier is illustrated in Figure 1. This development program was supported by the U. S. Navy, Bureau of Weapons, under the direction of the U. S. Naval Photographic Interpretation Center. The instrument is currently being tested and evaluated at its facilities in Suitland, Maryland. It is important, therefore, that it be understood that, while this paper does not necessarily reflect the official views of the Defense Dept., it does reflect their consideration to permit Bausch & Lomb, Inc. as prime contractor to present this report of the development program. Credit for the elec-

* Presented at the Society's 27th Annual Meeting, The Shoreham Hotel, Washington, D. C., March 19–22, 1961.

tronic wizardry so necessary in this modification belongs to the subcontractor, LogEtronics, Inc. of Alexandria, Virginia.

To best understand the instrument there must be known some of the reasons that prompted this project. The Autofocus Rectifier, by definition is a projection instrument for the photographic transformation of aerial negatives, particularly near-vertical or low-oblique exposures, into scaled and untilted positives which may be recorded on suitable photographic material, such as paper or film. One of the primary uses of these rectified prints is in the construction of controlled mosaics (Boughton and Sharp, 1948; Gruner, 1954). Assuming that accuracy requirements are met, the next most important consideration is that the adjacent prints used in the mosaic are carefully controlled in both tone and contrast. This is particularly desirable because basic interpretation of aerial photos relies on changes in tone and contrast for detection and recognition. To artificially introduce such differences where they do not belong adds a distraction to reliability.

REX R. MCHAIL

ABSTRACT: *A Bausch & Lomb Autofocus Rectifier was modified mechanically, optically, and electronically to provide the instrument with an increased capability of performing electronic dodging during photographic printing and automatic exposure control. A cathode ray tube was added as the photographic source from which a flying spot is scanned with a sensing unit using fiber optics. This feeds back through the electronics to modulate the velocity of the spot inversely with the density of the photographic negative resulting in electronic dodging. The scan-line spacing is automatically controlled as a function of easel tilt and magnification. The rectifier scale settings are set on the control dials of the electronic console, an exposure button is depressed and the negative is automatically dodged and exposure controlled.*

The causes of these tone and contrast anomalies are varied. Position changes of the airborne camera with its relation to the ground object and sun angle hot spot may impart a notable density difference of corresponding images on adjacent frames of the same film. Also, for any of a number of reasons, details within the negative may have a density range that is greater or less than desired. Other negative density variations may

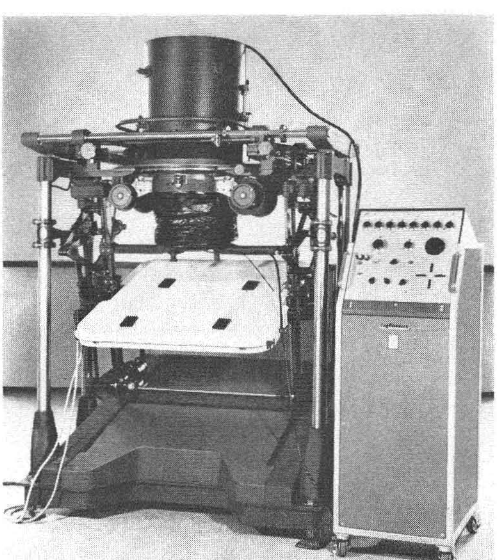


FIG. 1. The Bausch & Lomb Autofocus Rectifier modified for electronic dodging and automatic exposure control.

be caused by haze induced contrast reduction with changes in elevation or a lens—relative illumination variation. These factors, inherent in the negative, must be corrected (in addition to the correction to the geometry) either during the rectification printing or to a degree, in the processing of the resultant print.

Because of the laws of optics and light there are additional factors thrown in during the rectification printing process. When an image is projected onto a tilted surface, the light impinging on that surface varies with the cosine function of the angle of incidence. This causes the image to be progressively underexposed from foreground to background according to the angle of easel-tilt, unless it is carefully hand dodged during the exposure. This sort of gross hand dodging over the entire projected format is normally a trial-and-error method and is successful in proportion to the operator's skill, judgment and experience. In addition to over-all dodging of the entire negative, there are often portions within the negative that must be locally burned in or held back, by manual dodging, usually with a wand of some sort. Again, judgement, the limit of exposure time, the supply of test paper, and the patience of the operator become the limiting factors of success.

The purpose then is to produce rectified prints from aerial negatives that will be uniform in over-all appearance as well as uniform from print to adjacent print, and to be able to consistently and reliably reproduce these results with a minimum of operator effort and material waste.

The approach of this project was to utilize the electronic method of dodging to eliminate the need for hand dodging. The automatic exposure control is basically a refinement and by-product of the electronic dodging.

Figure 2 illustrates the Autofocus Rectifier before modification. Contrast this with the modified instrument of Figure 1. The first obvious differences are the change in the light source and the addition of the electronic black box, the LogEtron E-16 console, to the modified instrument.

The original light source consists of a grid of fluorescent tubes which produce a high visual intensity of light within the image area. It has been retained in the new instrument but has been considerably modified. This light source is used primarily during the initial set-up operation when a visual alignment is necessary to position the projected negative image onto a grid on the easel. In its operating position it may be used in exactly the manner as its original intent. The electronic light source is in a raised position directly over the fluorescent light source and negative stage. Figure 3 shows the fluorescent light source in its operating position. The raised handle of the upper structure and the thin line of clearance between the two show how the fluorescent source passes beneath the electronic source to occupy the exact position necessary over the negative stage. When not in use it is rolled conveniently to the rear of the instrument on rails.

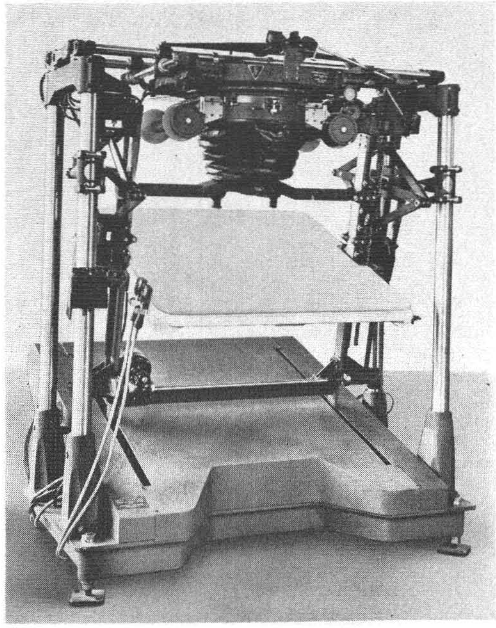


FIG. 2. The Autofocus Rectifier before modification.

Figure 4 illustrates the appearance of the electronic light source in its operating position. The fluorescent source has been rolled out of position on tracks toward the back of the instrument, and the printing source has been lowered within its protective housing downward to a position directly over the negative stage. This light source consists of a cathode ray tube with a 15 inch circular faceplate mounted face down over the film stage. Both light sources are equipped with limit switches which cut the power on or off when they are either in or out of operating position as desired.

The entire upper system, consisting of both light source and their support members, is mounted on x and y tracks so that they may partake in the necessary movements of the film stage and therefore stay automatically

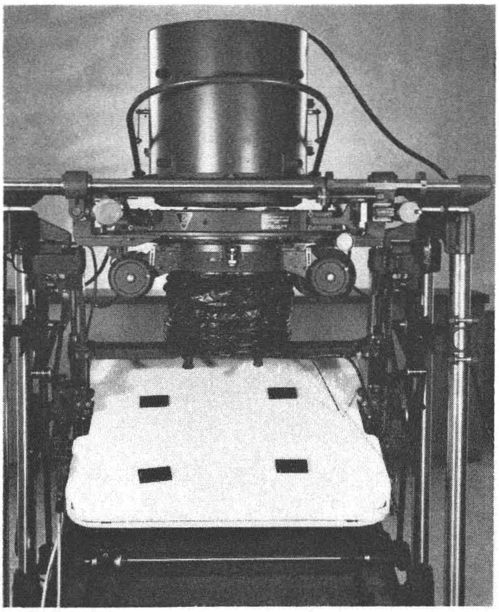


FIG. 3. The Fluorescent light source in its operating position.

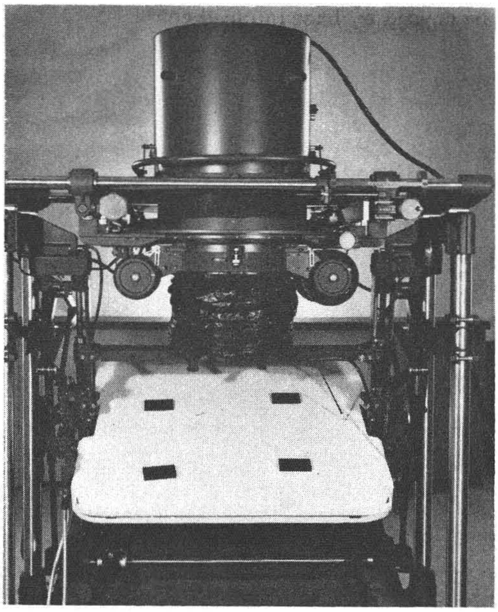


FIG. 4. The Electronic light source in its operating position.

centered over the negative. This is necessary to prevent limiting the full freedom of movement in x and y direction required in negative orientation.

The next item in the line of progression was the modification to the lens area. The lens, a $5\frac{1}{2}$ inch focal-length Enlarging Metrogon remains unchanged, but the space around it, enclosed within the enlarged bellows, underwent quite a transformation. The problem here merits further discussion.

The electronic dodging principle of photographic exposure control requires a feedback of light intensity after it passes through the negative in order to control the flying spot of the cathode ray tube source. Ideally then, if the light could be sampled as it passes through the enlarging lens and could be fed back from there, there would be obtained the desired control. Since this was physically impossible, several other approaches to the sampling problem were taken. A large ellipsoidal pellicle of optical quality was inserted at an angle between the negative and the lens to image a portion of the light onto a secondary lens system. This provided excellent results until the lens had to be severely tilted and the object conjugate shortened to accomplish a rectification of high-tilt and high-magnification. Then, the physical presence of the pellicle interfered with the narrowed confines of the available space.

The next approach was to attach a tiny, aluminized glass hemisphere to the rear vertex of the Metrogon lens. A microscope type lens system was directed at and focused on this lens, which would sample the flying spot reflections coming from it and provide the necessary feedback control. Again this system worked in principle for the normal, near-vertical rectifications, but because of the geometry of projection, there was produced an undesirable shadow-like masking effect at the higher tilts.

The final and highly successful approach to the light sampling problem was the utilization of glass-fiber optics. Twelve bundles composed of 15 micron diameter, coated fibers were placed around the upper lens cell of the "golf ball-like" Metrogon lens. Figure 5 shows the configuration of the 12 fiber bundles and the annular ring used to hold them in position. Each fiber literally looks at the image of the flying spot as it is reflected from the coated top surface of the rear lens element. The light which emanates from all directions off the lens surface is picked up collectively by the fibers in the 12 bundles. It is transmitted to a common channel where the fibers are mixed into a random arrangement. This is termed an incoherent fiber bundle. The purpose is to thoroughly mix the light over the end area where it then passes directly to the sensitive grid of a photomultiplier tube. The location of the photomultiplier tube is shown here by the horizontal position of the tube cover. The photomultiplier tube provides the feedback

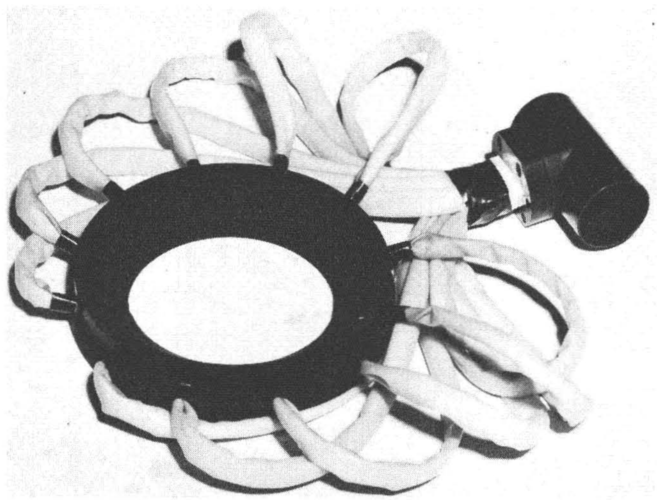


FIG. 5. Configuration of the 12 glass fiber bundles, annular ring and the photomultiplier tube housing.

energy to accomplish the electronic dodging control. The ultra-sensitivity of this system may be illustrated by the fact that the anti-reflection coating on the rear lens element reflects only 1% of the incident light. Without an anti-reflection coating it would reflect 4%.

The use of this novel fiber-optic system made possible a working design which could be fitted into the narrow confines available between the lens and negative stage under the most adverse operational conditions. The high transmission of coated fibers provided more than ample conductivity of the tiny flying spot reflection with relation to the sensitivity of the photomultiplier tube.

Next in the chain of discussion is that portion of the instrument which dictated many of the requirements of the foregoing components, the electronics. This instrument uses the latest developmental version of the LogEtronic principle called the LogEtron Model E-16 Control Console. Partial explanation of its function has already been given. The schematic diagram of Figure 6 gives an overall picture of the tie between the electronics and the mechanics and optics of the Rectifier.

The Model E-16 unit utilizes a similar but more highly sophisticated control than some of the earlier electronic dodging models (Craig, 1955). For the most part the former versions employ the technique of frequency modulation of the flying spot while the E-16 uses a unique velocity modulation control. This was necessary and desirable because of the printing time factor resulting from enlargement printing of large negative areas. The former method of rectification, that is using a fluorescent source, utilized one large powerful light source covering the entire negative during the exposure. A cathode ray tube as a light source makes use of a single fast-moving, very small spot which exposes the negative in incremental, small areas.

The velocity modulation technique was developed to fully utilize the inherent spot intensity at its maximum brightness. Instead of modulating the brightness of the spot as the means of dodging control, the velocity at which it moves is varied inversely with the amount of light permitted to pass through the various densities within the negative. Thus the flying spot incident on the negative remains constantly bright throughout an exposure, and the local exposure time becomes varied for different negative density sub-areas.

Also to insure the maximum of exposure energy available, a cathode ray tube was chosen with a P-11 phosphor. This cathode ray tube operated at a very high (10.5 Kilovolts) voltage, emits highly actinic blue light.

The E-16 Control Console when used with the modified Rectifier, automatically performs three functions normally undertaken by the operator of the standard Rectifier. These are:

1. Automatically dodging the print for variations in negative density.
2. Providing automatic exposure control.
3. Correcting for exposure changes within a print caused by the tilt of the easel.

Although the term automatically is liberally used, like every other so-called automatic device, someone must tell the electronics what

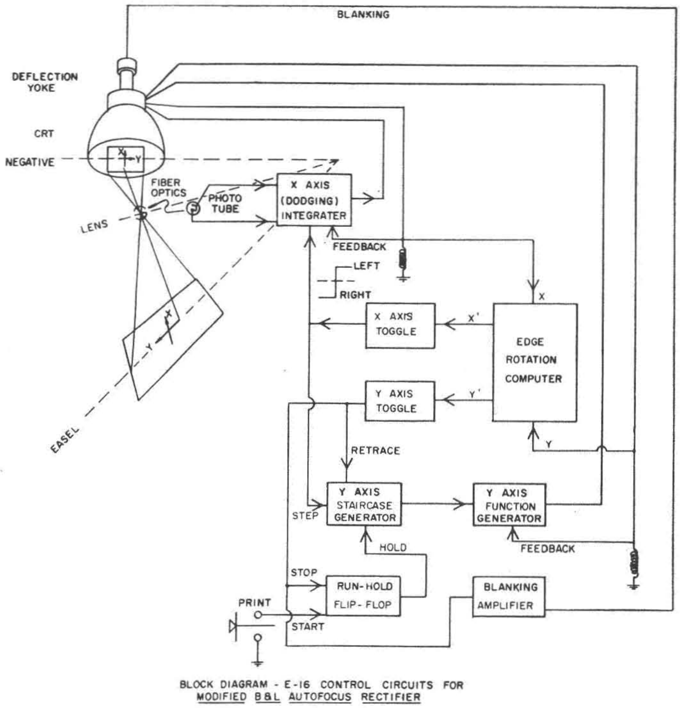


FIG. 6. Schematic diagram showing the tie between the electronics and the mechanics and optics of the Rectifier.

it desires it to do. This is the function of the Console Control Panel shown in Figure 7. Among the various controls are *on* and *off* switches and *set up* and *print* buttons with bull's-eye indicator lights for each. There is an *exposure index control* dial, and two dials to incorporate values as read from the Rectifier settings. These are the *lower conjugate distance* setting and the *Y displacement* of the film stage.

A series of eight dials across the top of the panel controls the *Exposure Correction for Tilt.* These values must be derived from precalculated graphs which provide information for the variety of conditions of tilts and magnification combinations. They impart a systematic correction to the exposure control for tilts by adjusting the scan spacing within eight parallel exposure bands across the negative.

In summary, the proof of the pudding in this case is in the final rectified print as shown in Figure 8. At the top is a rectified print made without any dodging, either electronic or manual, and lacking explosure control. A print of the same negative is illustrated at the bottom. It incorporates the full measure of control offered by the modified Autofocus Rectifier.

It is felt that this development is a step forward in the advancing technology of photogrammetry and photo interpretation, and occupies a place somewhere in the succession of advancement of the camera-lens-film and printing cascade.

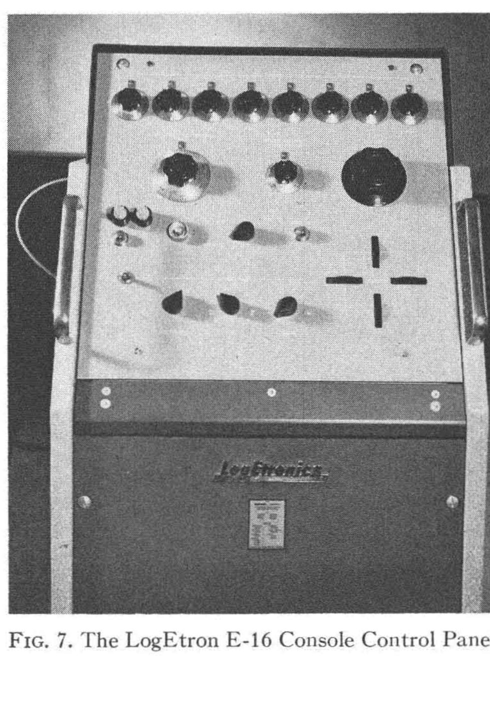
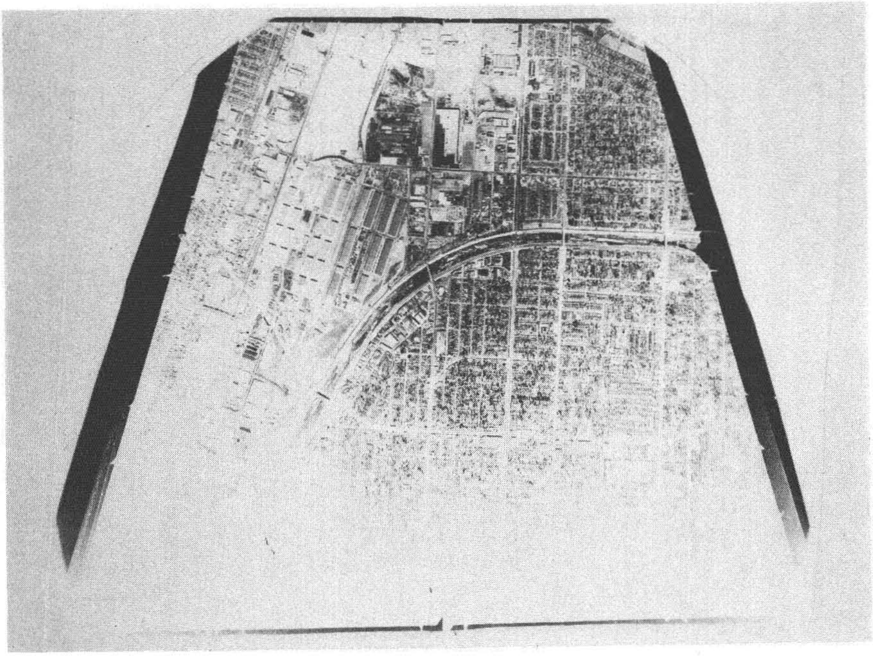
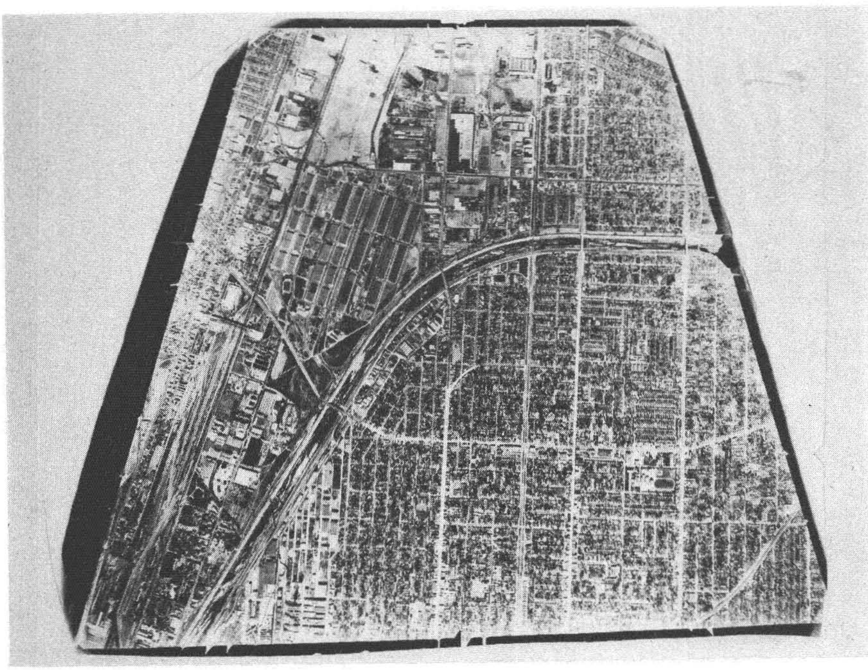


FIG. 7. The LogEtron E-16 Console Control Panel.



(A)



(B)

FIG. 8. Comparison prints showing (A) without any dodging, manual or electronic, and (B) with the full control of the modified Rectifier.

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