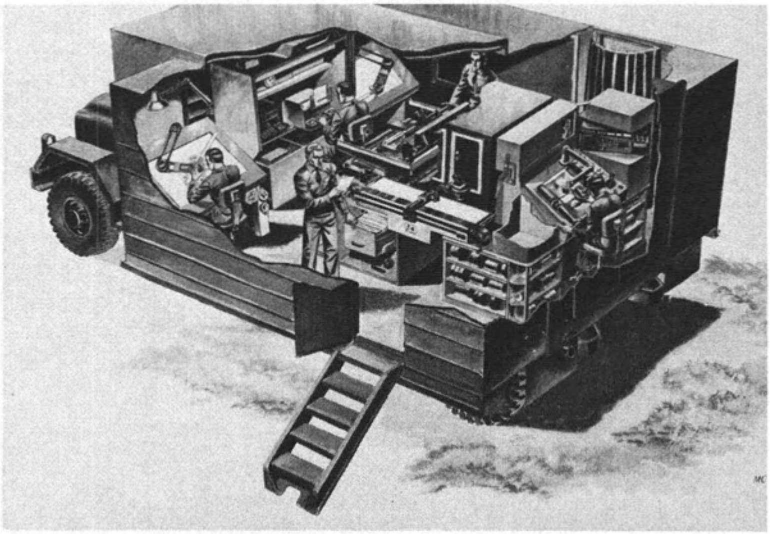


FIG. 1. General Layout of the Tactical Image Interpretation Facility AN/TSQ-43. TIIF.

CARL ORLANDO
U. S. Army Electronics Command
Fort Monmouth, N. J. 07703

Tactical Image Interpretation Facility

A van contains a measuring viewer encoded directly into a computer.

(*Abstract on page 96*)

DURING WORLD WAR II and the Korean War, image interpretation was accomplished by photographic interpreters (PI) using simple-stereoviewers, drafting compass and rulers in locales not necessarily assigned or intended specifically for photographic interpretation. The photographic interpreter often performed his task under adverse operating conditions and, in many instances, under a tent with poor lighting facilities. This simple technique resulted in slow interpretation of imagery and a low confidence factor for accurate interpretation.

Since the Korean War, and with the advent of the more sophisticated surveillance sensors, such as Side Looking Radar (SLAR), Moving Target Indicator (MTI), and infrared, coupled with the advanced design of aerial photographic systems, and the necessity for continuous surveillance, the inadequacy of the Photo Interpretation Kit with its simple tools has been demonstrated. The PI, or what should now be called the Image Interpreter, is required by his commander to extract information from these sensors in the shortest possible time, in order that timely and adequate countermeasures may be taken to counteract the enemy. The Army has increased its interpretation capabilities with the development of the Tactical Image Interpretation Facility (TIIF) AN/TSQ-43.

THE TACTICAL IMAGE Interpretation Facility, is a self-contained equipment mounted in an expansible van for extracting intelligence information from photographic, radar, and infrared imagery. A number of viewers are employed for magnifying the imagery

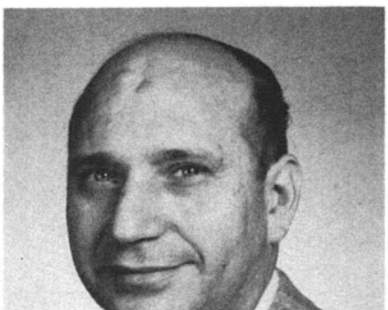
FIG. 2. Interior of TIIF. The light table is shown on the left and the stereo viewer to the right of the photograph.

under investigation. The results and observations are transmitted to the requesting commander by using telephone and teletypewriter equipment included in the TIIF.

The imagery (paper positives and transparencies) may originate from Army, Navy, Air Force, and other agencies. This imagery is received in rolls of film or paper, and in cut sheets. The different formats which can be accommodated are: $2\frac{1}{4}$ by $2\frac{1}{4}$ inches, $4\frac{1}{2}$ by $4\frac{1}{2}$ inches, 9 by 9 inches, and 9 by 18 inches; and 70 mm., 5-inch, and 9-inch panoramic strips photography. Radar and infrared imagery produced on strip of 70 mm., 5-inch, and $9\frac{1}{2}$-inch film can also be interpreted in this facility.

The TIIF, is employed at Division, Corps and Field Army. One or more of these units may be employed depending on the workload of the echelon. Operationally the equipment is located as closely as possible to the information gathering sensors, airfield and drone sites, and to the photographic processing vans. The TIIF provides 24-hour image interpretation service to the commander. In normal operating workloads, five image interpreters are housed in the TIIF. Under very heavy workloads, as many as ten image interpreters can be accommodated.

FIGURE 1 SHOWS the general layout of the Interpretation equipment and the major components which include the cabinet space and viewer-computer. The illustration shows the van expanded to allow work space around the interpretation equipment. Two Light Tables are located, one on each side of the Van. Figure 2 shows, to the left of the photograph, one of these devices. This equipment is primarily used for the preliminary scanning of imagery for obtaining intelligence information for use in initial or so called Hot-reporting. However, it can also be used for detail study of the imagery for reporting more complete information. It is provided with a glass top surface 11 inches wide by 40 inches long and illuminated with a cold cathode light



CARL ORLANDO

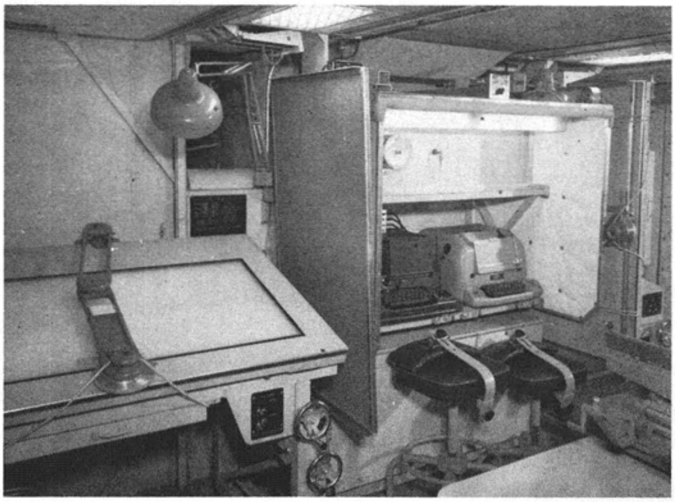


FIG. 3. Plotting tables. One in position, to the left, and the other collapsed, to the right of the photograph. The communication booth is shown in the center.

source which provides continuously varying illumination over a 20 to 1 ratio. Illumination of 1,200 foot-lamberts is possible. Suitable masks are provided to eliminate glare of the surface not covered by the film being examined. A vacuum hold down maintains the film area flat. A microscope carriage is provided to hold a microscope and stereoscope for observing the imagery.

The imagery may be in roll form up to 500 feet capacity, 70 mm. to 9½ inches wide, and cut sheets to cover the entire area of the light table. As part of the light tables there are provided two stereoscopes for use with 5-inch and 70 mm. stereo photography. These instruments, by interchanging proper lenses, can also be used to view imagery of all sizes in two dimensions. Optical power pods are supplied having a continuous magnification ratio of 0.7 to 3X. With proper selection of objective lens and eyepiece, magnification up to 120X can be accomplished.

THE STEREOSCOPIC VIEWER, shown to the extreme right of Fig. 2, accommodates stereo viewing for film widths of 5 inches and 9½ inches, up to 1,000 feet in length. The direct viewing optics (not visible in this illustration) are designed for continuous variable magnification from 2.5X to 25X. The platen is provided with vacuum-hold-down device for flattening the photography under examination. A continuously variable light source is provided similar to that used in the light table.

Two plotting tables are provided in the forward portion of the van, left portion of Figure 3, to allow the image interpreter to view imagery and make photographic mosaic or overlay. The surface is provided with a variable light source similar to the other equipments, and is used for viewing transparencies. An overhead light permits examining opaque prints. The tables are designed to be raised out of the way to allow the van to be closed during transport as shown in the extreme right of Fig. 3.

A VIEWER COMPUTER is included, (Figure 4), and is mounted in the rear of the van for viewing imagery and obtaining ground measurements. The viewer portion consists of two light tables and means for holding films from 70 mm. to 9½ inches wide up to 500 foot spools. A microscope is provided for observing target details and for aiding in positioning a measuring cursor. The cursor consists of a projected light, which can be positioned in any point on the image by means of a "joystick" control.

A computer forms part of this equipment. This is a Field Data Digital Army computer, M-18(FADAC), adapted for this application by proper programming. The computer receives its input from X-Y encoders activated by the cursor movement. The mechanical accuracy is obtained by means of X and Y lead screws which maintain the movement of the cursor within the stringent requirements. The encoder, which transforms the analog movement of the lead screw to digital inputs to the computer, is set for bit informa-

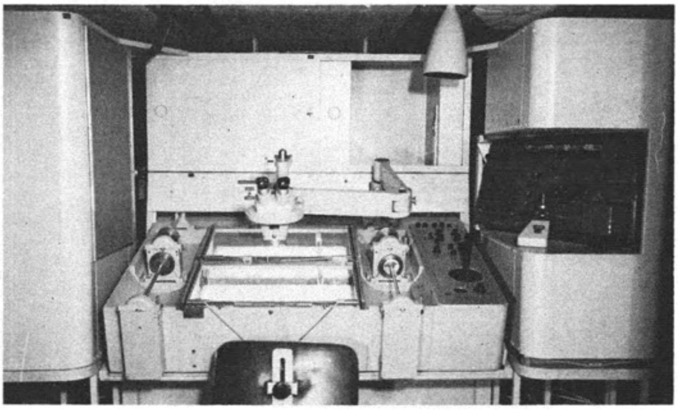


FIG. 4. Viewer-computer. Note computer Matrix to the right of photograph.

tion of 12 microns. The computer is in turn programmed to compute this input into a 32-bit word for a total memory 8,192 words. This capability produces a mensuration instrument which can measure down to 25 microns. In the full length of the Y direction of 18 inches, it is possible to measure within an error of 1 part in 5,000.

The computer is programmed for rectifying the image under observation and obtaining ground distances; heights of objects, using the displacement technique and stereopair methods; ground areas; and distances of winding roads. Further, it can determine distances of objects located in more than one frame, distances of two points located at different altitudes, and determine map coordinates of targets under observations in either geographic or universal transverse mercatory system, (UTM). Rectification of oblique and panoramic photography can be accomplished as well as that of infrared and radar imagery. The output readout is in the form of nixie tube numerical presentation and hard copy teletypewriter. The computation is done automatically after the operator has programmed the computer with the known variables applicable to his problem.

Mensuration computations are achieved by the operator of the viewer computer by inserting the proper parameters in the computer. These parameters include, focal length of lens, altitude of the aircraft, attitude of the camera (obliquely), type of sensor under examination, e.g., photo, infrared or radar, and the special parameters associated with them. These factors are programmed into the computer by pressing the appropriate buttons identifying the known variable. The computer is then set for operation and an automatic readout of the desired information is obtained. For instance, if the ground distance between two points is desired after inserting the proper parameters in the computer, the operator first moves the cursor to one point and turns an Initial Set knob. He then moves the cursor to the second point and turns the "Compute knob". The computer automatically displays on nixie tubes or teletypewriter readout the distance covered on the ground. The computer compensates for oblique as well as for panoramic distortion of photographic imagery, and known distortions of infrared and radar imagery.

OTHER EQUIPMENT provided are five Photo Interpretation (PI) kits containing rulers, dividers, simple stereo viewers, and drafting instruments. This equipment is self-contained in a carrying case which can be used outside of the TIIF for limited on-the-spot image interpretation.

Filing cabinets are provided for efficient storage and quick retrieval of roll and cut sheets imagery. Space is provided to store paper maps and for storing image interpretation keys.

The communication equipment within the van consists of a telephone, a teletypewriter and a reperforator. (Figure 3, center of photograph).

The TIIF is also provided with heater and air-conditioning for maintaining efficient working conditions for the image interpreters and to keep the optical and electrical equipment in an optimum operating environment.

As part of the storage facility, an optical carry case is provided (Figure 5). This case performs a dual purpose. It is used to store the optical equipment during transit for shock and vibration protection, and it serves as a conditioning environment for the optics in very cold weather operation. It is well known that optics will fog when submitted to a sudden change in temperature from cold to hot. This condition would prevent quick use of the optical instruments in an atmosphere rising in temperature, if stored open in a cold van. The optical case provides for air tight atmosphere which is first heated so that when the optics are removed to the warmed van no fog is formed on the inside or outside surfaces.

The viewer computer described briefly previously is one of the most versatile items equipment in the TIIF. This equipment, which combines viewing and computation capabilities, allows the image interpreter to perform Photogrammetric computations which would otherwise take an unreasonable length of time to perform or, in many instances, it would require such complex computations that it would be impossible to undertake at the echelon of operation. This point can best be illustrated by referring to Figures 6 to 10.

ABSTRACT: *A Tactical Image Interpretation Facility (TIIF) contains viewing equipment for extracting surveillance information from photographic, infrared, and radar imagery. The facility also includes a computer connected to a viewer for obtaining photogrammetric information from the imagery. After the appropriate inputs are programmed to the computer, automatic readout and image distortion compensation are obtained from the computer for such factors as ground linear distance, heights of objects, curvilinear distances, area, target location in UTM or geographic coordinates of objects within the imagery, and other parameters useful to image interpreters. These measurements can be made to within 25 microns of the distance covered in the imagery. The facility is self contained in a van which is provided with air conditioning and heating to maintain the working ambient temperature within comfortable limits.*

FIGURE 6 ILLUSTRATES a grid of uniform areas. This grid represents the results of photographing a similar grid using a true vertical photograph where theoretically no distortions are present. Here, distances on the ground are proportionally represented on the photograph, so that any point may be defined in terms of simple X and Y coordinates.

Figure 7 is the resultant photograph of a ground grid of Figure 6 using an oblique photograph. In this case distortions present in the image are caused by the position and orientation of the camera relative to the ground, and are related to the swing and tilt angle as well as to the focal length of the camera lens used. This relationship may be expressed by the following:[1]

$$X'' = X'/[\cos t - (Y'/f) \sin t]$$

$$Y'' = Y'/[\cos t - (Y'/f) \sin t] \cos t$$

where

$X' = -X \cos s + Y \sin s$
$Y' = -X \sin s - Y \cos s$
s = swing angle
t = tilt angle
f = focal length
X, Y = image coordinates
X', Y' = corresponding image coordinates of a reference system which has been rotated to correct for swing
X'', Y'' = corresponding coordinates of X' and Y' after projection to a plane of constant scale (vertical frame equivalent) to correct for tilt angle.

FIGURE 8 IS THE resultant photograph of a ground grid of Figure 6 using a panoramic camera. Here the grid is modified by three super-imposed distortions. The first distortion is due to the geometry of the focal plane and sweeping action of the lens relative to the orthographic aspect of the grid being photographed, and would be present even without motion of the aircraft. Secondly, there is a distortion due to the time interval of angular sweep movement of the lens while the vehicle is moving at the time the photograph is taken. Thirdly, distortion is due to the IMC (image motion compensation) introduced by the camera mechanism during the interval the photograph is taken.

In this case expressions for the rectified coordinates are more complex because of the additive effects of the distortions mentioned.[2,3] These relationships are given in terms of the following:

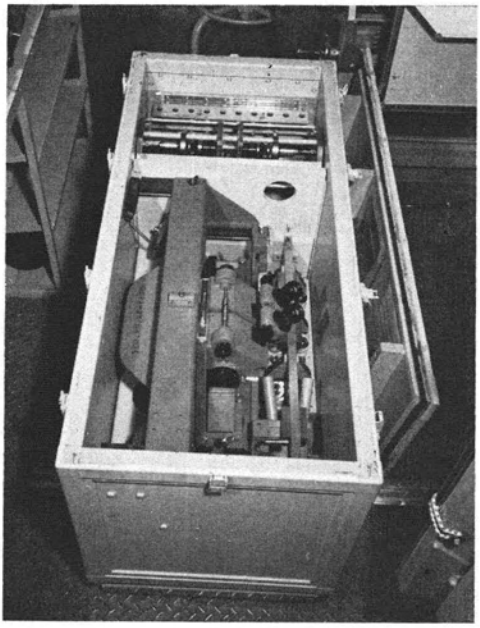


FIG. 5. Optical carrying case.

T = tilt
s = swing
X, Y = image coordinates
X', Y' = rectified image coordinates
β = Y image coordinate after correction for image motion control
f = focal length
ω = angular sweep velocity in radians per second
θ = sweep angle of panoramic photograph in radians
t = time of sweep in seconds
V/H = ratio of aircraft velocity to aircraft altitude
l', m', n' = direction cosines of image object rays in image space
l, m, n = direction cosines of image object rays in object space

On a panoramic photo $\theta = X/f$ and the sweep time is $t = \theta/\omega$

Corrections of the Y-image coordinate for image motion control is given by

$$\beta = Y - (V/H)(f/\omega)\sin\theta$$

and the direction cosines of the image space systems of any object ray are

$$l' = \beta(\beta^2 + f^2)^{1/2}$$
$$m' = f\sin\theta/(\beta^2 + f^2)^{1/2}$$
$$n' = -f\cos\theta/(\beta^2 + f^2)^{1/2}$$

The image direction cosines are translated to vertical oriented object space direction cosines by the equations

$$l = -l'\cos S + m'\sin S$$
$$m = -l'\cos T\sin S - m'\cos T\cos S - n'\sin T$$
$$n = -l'\sin T\sin S - m'\sin T\cos S + n'\cos T$$

and these final rectified coordinates are determined by

$$X' = f[(V/H)t - l/n]$$
$$Y' = -f(m/n)$$

Figure 9 is the resultant photograph of Figure 6 using infrared strip photography. In this case the distortion is due to the line scan technique used in IR.

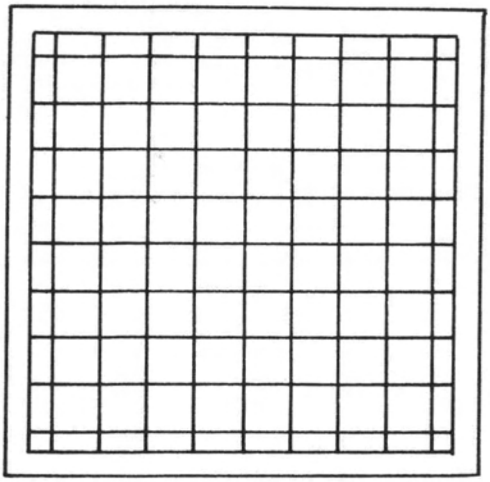


FIG. 6. Grid of uniform area simulating a vertical photograph.

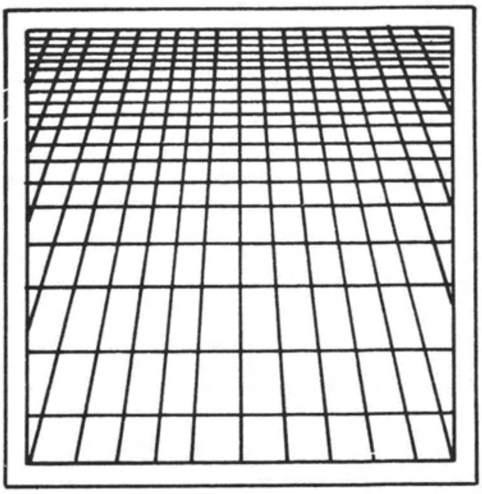


FIG. 7. Grid simulating an oblique photograph.

THE DISTORTION is more evident when the terrain being photographed contains image components, such as roads, which are not perpendicular to the line of flight. A number of factors must be considered in this case which are evident in the following equations.[4] Note that an added correction has been included FLS, which is the distortion due to forward movement of the aircraft when scan synchronization relative to aircraft ground velocity is not constant.

$$f = I_w/\theta$$

$$Y' = f \tan (y/f)$$

$$X'' = (FLS)f \cdot X/(H - \Delta H) + f \tan t_Y$$

$$Y'' = f(Y' \cos t_X + f \sin t_X) \div (f\cos t_X - Y' \sin t_X) \cos t_Y$$

where

X, Y = image coordinates
Y' = partially rectified coordinate
X'', Y'' = Rectified coordinates
f = equivalent focal length
t_X = component of tilt in X-Z plane
t_Y = component of tilt in Y-Z plane
I_w = Image width
θ = scan angle
H = Altitude of aircraft above datum plane
ΔH = height of object above datum plane
FLS = flight line scale = ratio of aircraft velocity to film velocity

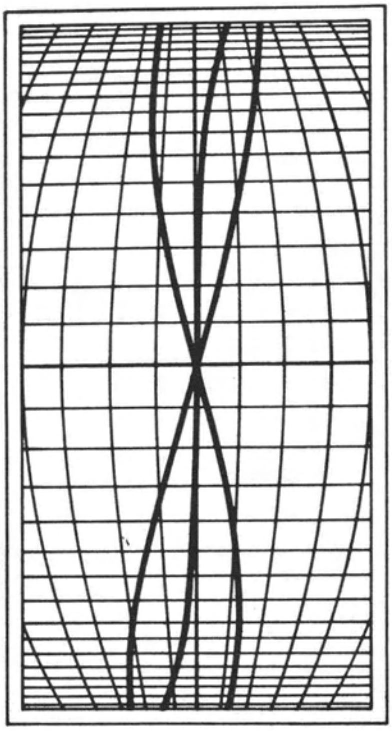


FIG. 8. Grid simulating a Panoramic photograph.

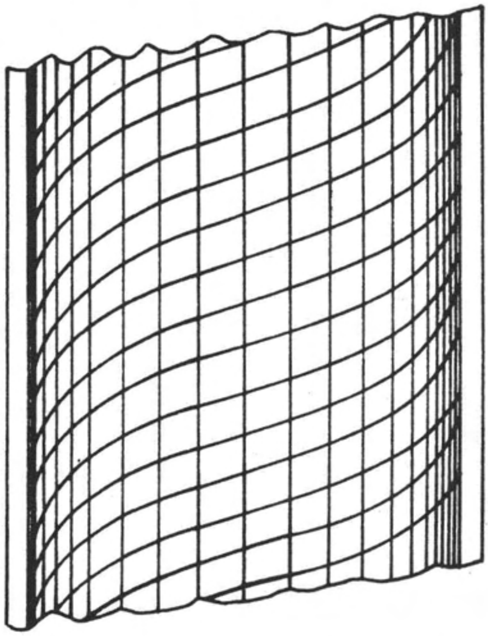


FIG. 9. Grid simulating infrared imagery.

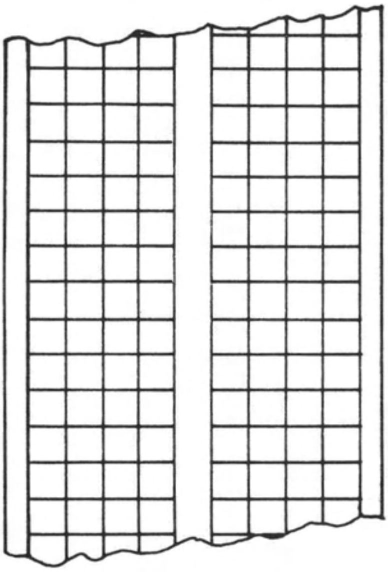


FIG. 10. Grid simulating side looking Radar (SLAR).

FIGURE 10 shows the resultant imagery of a side looking Radar (SLAR). In this case the grid lines are symmetrical because usually SLAR techniques rectify the image electronically before it is displayed.[4] NOTE: The center portion of the grid is not recorded.

The rectification may be expressed as follows:

$$f = (I_w/R)H$$

$$X'' = (FLS)f \cdot X/(H - \Delta H) + f \tan t_Y$$

$$Y' = \left\{[H/(H - \Delta H)]^2(Y^2 + f^2) - (f/\tan t_Y)^2\right\}^{1/2}$$

$$Y'' = \pm Y'$$

The sign of the various components must be examined to determine the sign to be assigned to the radical. Here,

- X, Y = image coordinates
- Y' = partially rectified coordinate
- X'', Y'' = rectified coordinates
- f = equivalent focal length
- t_Y = component of tilt in Y-Z plane
- I_w = Image width
- R = Range
- H = Altitude of aircraft above datum plane
- ΔH = height of object above datum plane
- FLS = flight line scale = ratio of aircraft velocity to film velocity

These formulas have been presented to introduce the reader more intimately to some of the problems related to rectification of imagery produced by the newly developed sensors. It is suggested, however, that the reader refer to the references indicated for a more detailed treatment of this subject.

THE TIIF WAS DEVELOPED by the U. S. Army Electronics Command, Fort Monmouth, N. J., under contract with General Precision Inc., Link Division, Binghamton, N. Y. Four R & D models were procured in the initial development. These have proven very successful and an additional quantity of 25 units is now being manufactured.

The author is indebted to Mr. G. Young of General Precision Inc. for his contribution in the development of the equipment, to Dr. Lisman, USAECOM, for his help in the mathematical aspects of this project, and Mr. F. Ivins, USAECOM, for his help in conducting the evaluation of the equipment.

REFERENCES

1. MANUAL OF PHOTOGRAMMETRY, American Society of Photogrammetry.
2. ASTIA, Final Report EN-71( ), Rectifying Projection Printer, dated 16 Nov. 62. Contract No. DA36-039 SC-48929.
3. Photographic Science and Engineering, Vol. 5. Page 257–261 (1961). P. P. Paris and K. Leistner.
4. ASTIA, Final Report. Tactical Image Interpretation Facility. AN/TSQ-43. Contract No. DA36-039 SC-90888.

Notice to Authors

1. Manuscripts should be typed, double-spaced on $8\frac{1}{2} \times 11$ or $8 \times 10\frac{1}{2}$ white bond, on *one* side only. References, footnotes, captions—everything should be double-spaced. Margins should be $1\frac{1}{2}$ inches.
2. *Two* copies (the original and first carbon) of the complete manuscript and two sets of illustrations should be submitted. The second set of illustrations need not be prime quality.
3. Each article should include an abstract, which is a *digest* of the article. An abstract should be 100 to 150 words in length.
4. Tables should be designed to fit into a width no more than five inches.
5. Illustrations should not be more than twice the final print size: *glossy* prints of photos should be submitted. Lettering should be neat, and designed for the reduction anticipated. Please include a separate list of captions.
6. Formulas should be expressed as simply as possible, keeping in mind the difficulties and limitations encountered in setting type.