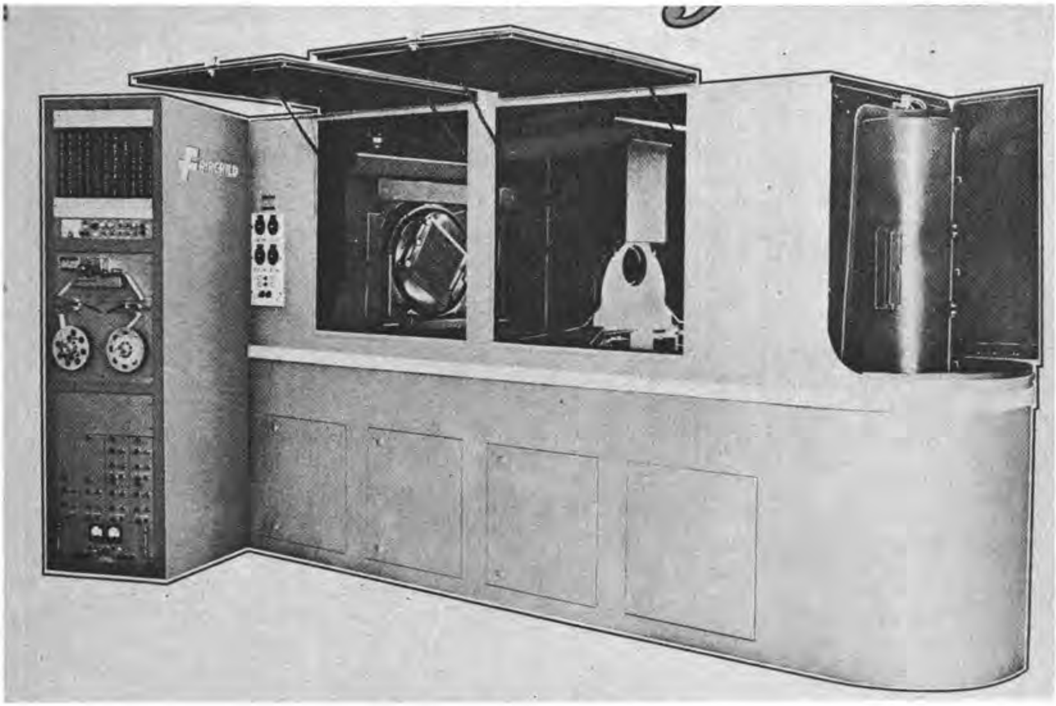

FIG. 1. Electro optical rectifier.

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Electro-Optical Rectifier

Fairchild device used slit-can with programmed lens and copy motions for frame, strip, and panoramic photography.

(*Abstract on next page*)

FOR THE PAST 15 to 20 years, ACIC has been engaged in rectifying many types of reconnaissance photography for various phases of its mosaicking and charting programs. A variety of optical projection-type rectifiers, each having its own inherent capabilities for rectifying a particular type of frame photography (i.e., focal length, tilt and magnification) was used for such rectifications. Included were such rectifiers as the Bausch and Lomb, the SEG IV and V of Zeiss, the RP-6 of Saltzman, and the RP-2 of Fairchild.

The recent advances in resolution and quality of panoramic photography, as well as the continued use of improved quality small-scale frame photography, including super-wide angle photography, has greatly increased the requirements for a wide variety of rectifications. Conventional approaches to panoramic

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rectifications generally tend to restrict the use of a panoramic rectifier to one particular focal length and magnification.

In order to provide a universal rectifier which could accommodate the many types of photography available, under development or possible future development, Rome Air Development Center contracted with Fairchild Camera and Instrument Corporation to design and build such an instrument (Figure 1). In 1961 Mr. Samuel W. Levine, the designer, described the capabilities and features of such an instrument.[1] In brief, the instrument uses a slit scan projection system in which the rectification in the Y-direction (Figure 2), perpendicular to the principal line of the photography, is accomplished by the programmed variable motion of the lens and copy platen. The rectification in the X-direction, along the principal line, is obtained from the relative motion between the copy platen and the recording cylinder. The scanning of the copy platen (Figure 3) is from the direction of the horizon line of the photography toward the nadir at a variable speed. The recording cylinder (Figure 4) is rotated at a constant high or low speed and will accommodate up to a 36-×-36-inch size negative. Several copy platen format sizes are available and include sizes up to 9×9 or 5×13 inches.

ABSTRACT: *The capability of the Fairchild Electro-Optical Rectifier is described in terms of the types of materials that have been generated by the instrument, and the photographic and geometric quality of these products. This new rectifier uses a slit-scan projection method with rectification being accomplished by the programmed motion of the lens and copy platen for transformation of the y-axis perpendicular to the principal line of the photography, and the relative motion between the copy platen and the recording cylinder for transformation on the x-axis along the principal line. Specific examples of various types of frame, strip, and panoramic rectifications of both grid and photographic materials made with the Fairchild Rectifier show the operational capability and photographic quality attainable with the instrument. A unique application is the rectification of sections of telescopic photographs of the lunar surface.*

Two separate lenses (Figure 5) of 7.85-inches and 14-inches focal lengths permit a continuous range of magnifications from 0.5× to 9×. The rectifier will accommodate oblique frame, panoramic, and oblique slit or strip photography, with focal lengths of 3 inches to 100 inches and greater, and tilts to 80 degrees. The elements of rectification are precisely computed by a digital computer, for each of the possible 3,600 scan lines, from the input parameters to the computer program. The input parameters are the focal length and tilt of the photography, the altitude from which it was taken, the magnification desired, the area of the photograph required, etc. This rectification data is converted into rectifier dial settings of lens and copy-distance scan speed, recording-cylinder speed, and other data required for each scan. The rectifier data is punched on a 7-channel paper tape which drives the rectifier through the digital decoder (Figure 6).

Since up to three hours of RCA 501 computer time are required to prepare a tape for each focal length, tilt and enlargement required, a library of tapes has been made at ACIC for all commonly encountered tilts, focal lengths, enlargements, etc. In order to transmit the maximum accuracy from the precisely computed tilt data to the rectified

ARNOLD F. TRACHSEL

[1] Levine, S. W., "A Slit-Scan Electro-Optical Rectifier," *Photogrammetric Engineering*, December 1961.

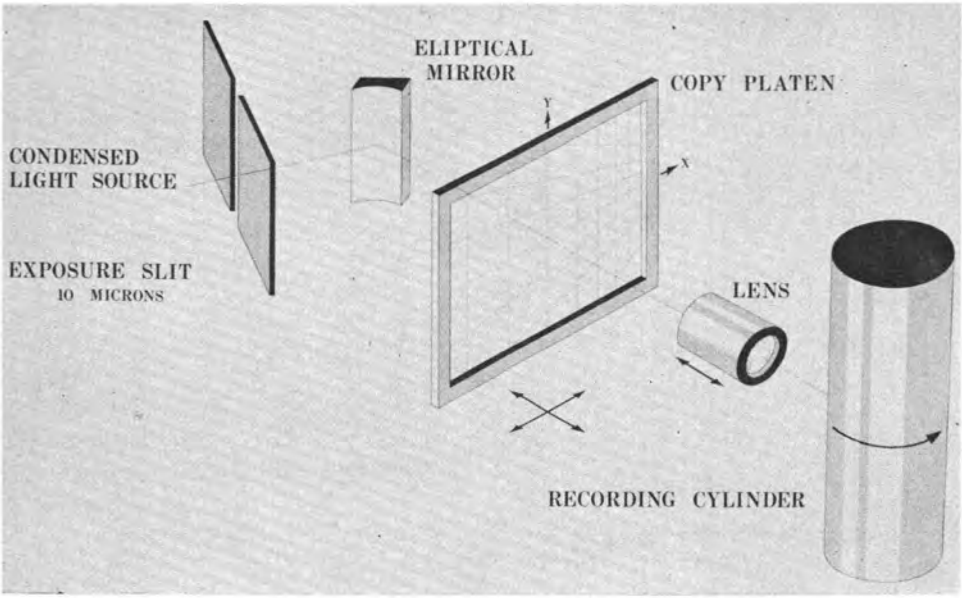

FIG. 2. Rectifier schematic.

positive, a special punching device was devised to permit positioning the negative in the copy holder.

The resolution capability of the rectifier was determined by projecting a high contrast USAF 1,000:1 resolution target through the

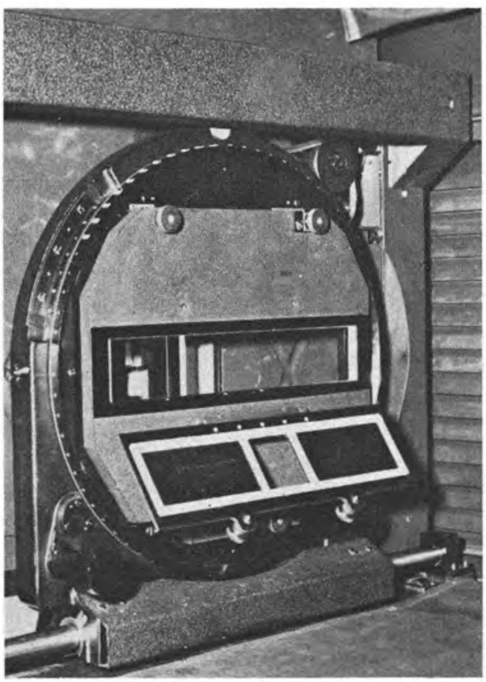

FIG. 3. Copy platen (70 mm. frame).

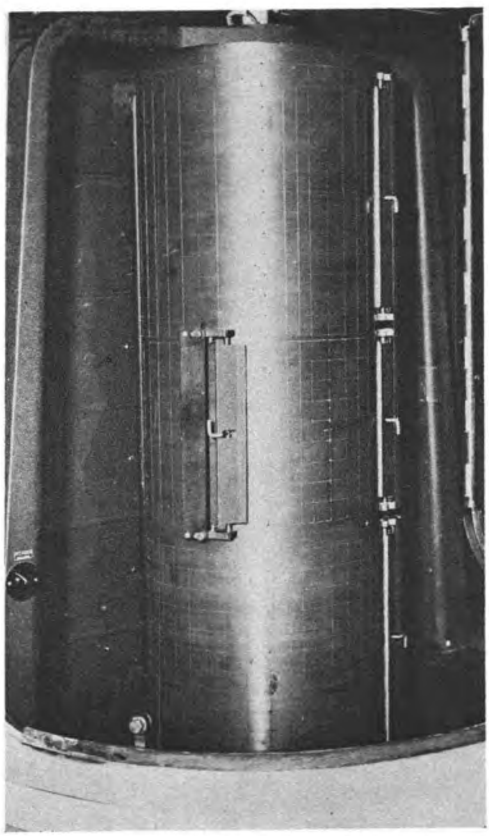

FIG. 4. Recording cylinder (36×36 inch maximum film size).

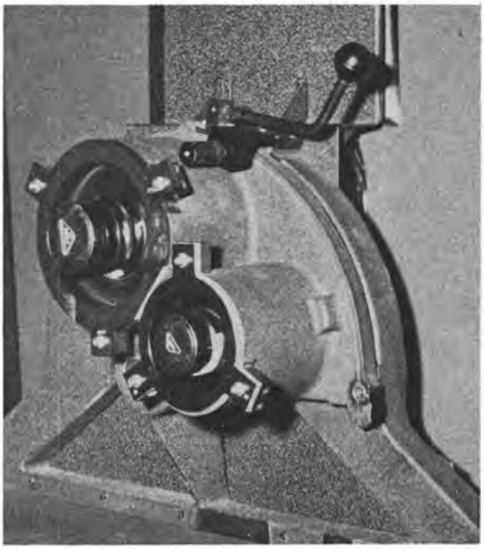

FIG. 5. Lens carriage.

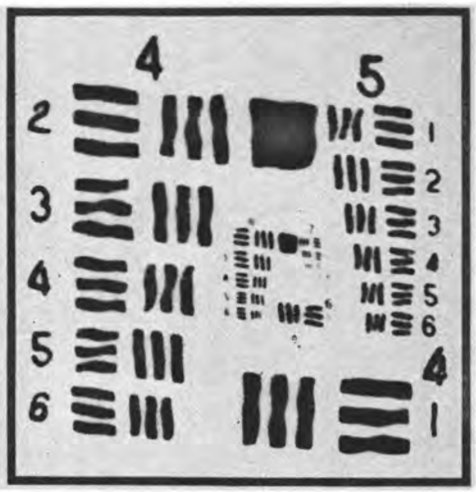

FIG. 6. Resolution from 7.85-inch lens: 128 lines/mm., 20° tilt.

system at various magnifications. Resolution of 128 lines/mm was obtained with the 7.85-inch lens with a tilt of 20° and a magnification of 4 times (Figure 7). The 14-inch lens was able to resolve only 64 lines/mm; as a consequence, various methods have been used to induce into the program tapes data which would cause the automatic selection and use of the better lens whenever a programmed choice exists. In other cases, the magnification has been altered to permit maximum resolution. Due to the long focal lengths which can be accommodated by the rectifier, it is possible to enlarge materials on a high quality enlarger prior to rectification, and thereby further increase the final resolution obtainable. The optical-mechanical limitations of conventional types of rectifiers, as well as resolution limitations, have greatly restricted their use

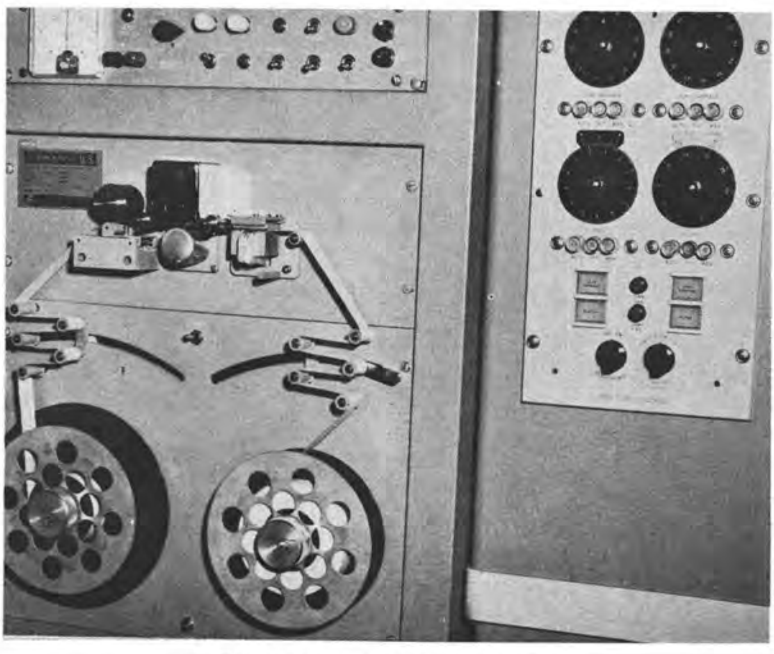

FIG. 6. Control panel and decoder.

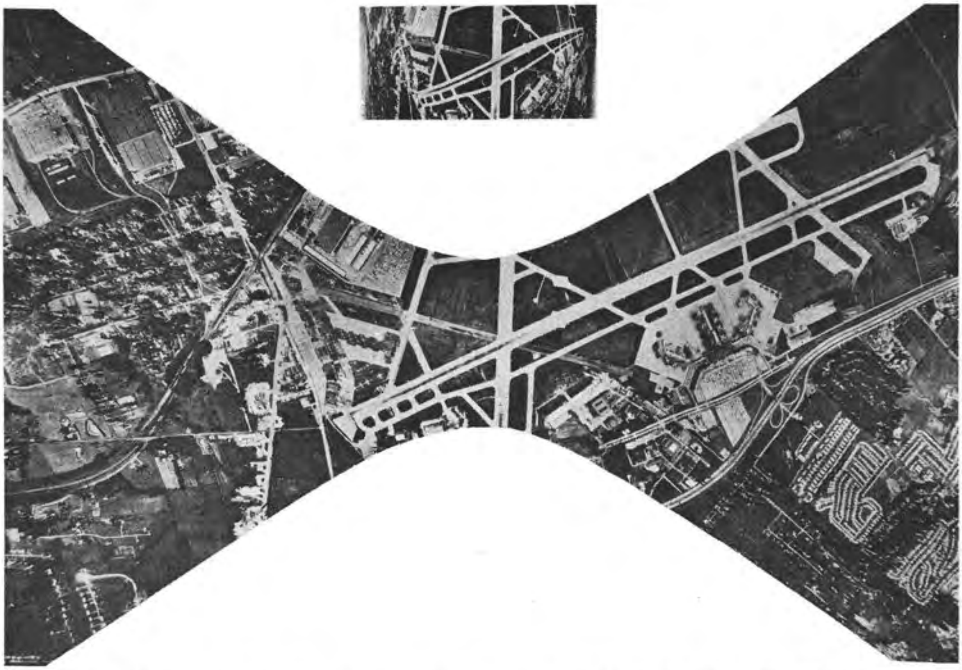

FIG. 8. Panoramic Rectification (Lambert Field, 1:5,000, $f=3$ inches, $H=2,000$ feet)

for the rectification of long focal-length photography, and prohibit the use of such methods.

The accuracy of the rectifier was determined by rectifying a 5-mm calibration grid plate for various tilts and focal lengths, and analytically computing the resultant tilts. The maximum error of rectification was 5 minutes of arc for angles up to 60 degrees.

In order to demonstrate the wide capability and versatility of the rectifier, a number of

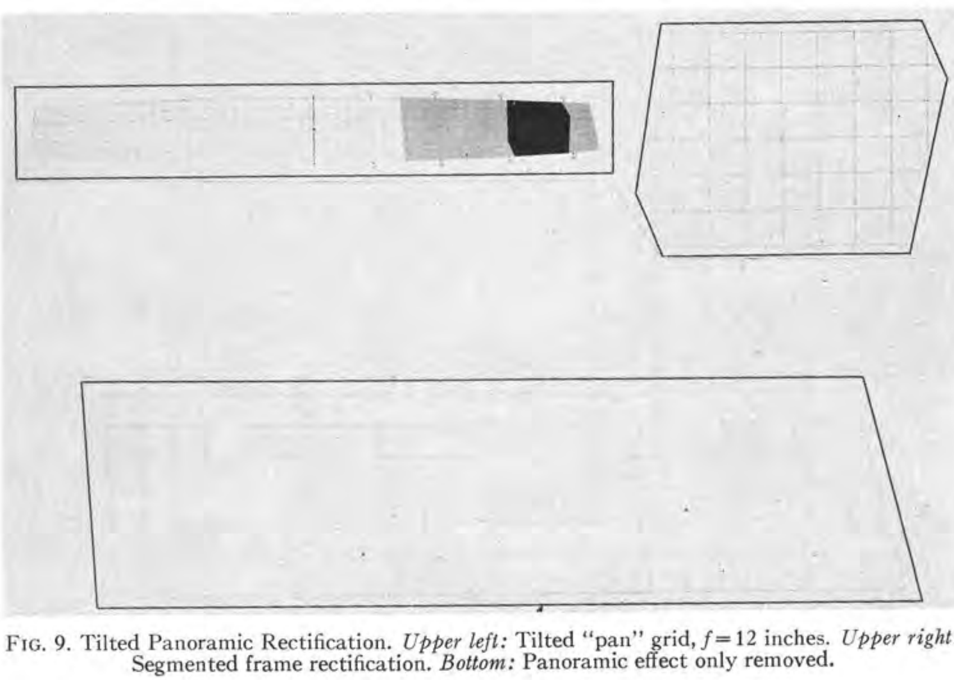

FIG. 9. Tilted Panoramic Rectification. *Upper left:* Tilted "pan" grid, $f=12$ inches. *Upper right:* Segmented frame rectification. *Bottom:* Panoramic effect only removed.

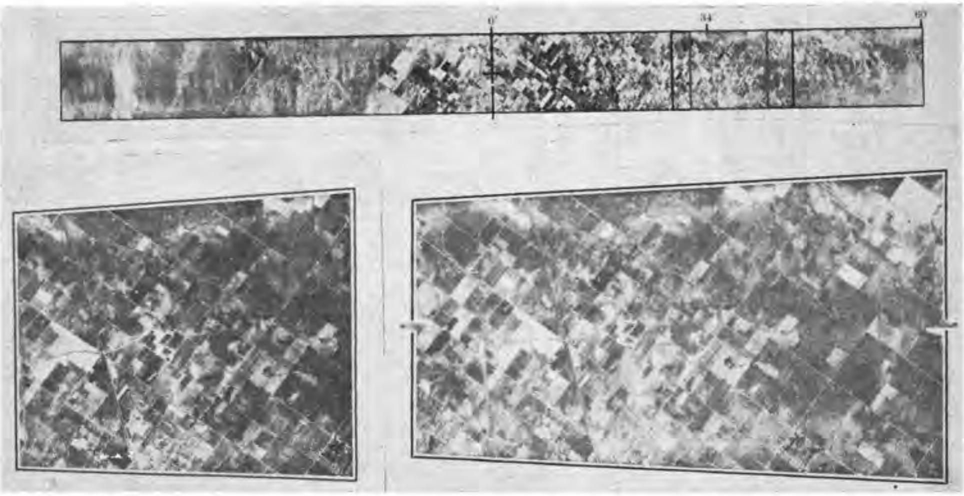

FIG. 10. Segmented Panoramic Rectification. *Top:* Contact print, $f=12$ inches, Arizona Test Area. *Left:* Frame program. *Right:* Panoramic program.

examples of rectifications have been prepared from various types of photography available, or simulations of types of photography possible.

Figure 8 shows the rectification of a panoramic photograph taken at a flying height of approximately 2,000 feet with a 3-inch focal-length panoramic camera over Lambert Field, St. Louis. The lack of complete rectification, as evidenced by the non-prependicularity of the ends of the runways and the intersections of streets, is due to the presence of pitch which was not removed from the photography. The complete rectification of pitched panoramic photography requires two stages on the rectifier, one to remove the panoramic effect and one to remove the pitch. Approximate rectifications of such photography can be accomplished for small segments of the photograph by rectifying these segments as frame photographs with tilt equal to that of the center of the segment. The maximum rectification error induced by this approximate rectificaion using a 2-inch square area from a 12-inch panoramic photograph differs from a correct rectification by 0.01-inch at 1:1 magnification. An example of such a rectification is shown (Figure 9) by this 15° pitched, 12-inch focal-length grid rectification. The center of the "chunk" is 34° from the nadir of the photograph. The lower part of the figure shows one half of the grid rectified for the panoramic effects only. The segmenting concept applied to vertical panoramic photography (Figure 10) is illustrated by this 12-inch focal-length "chunk" and panoramic rectification taken at an altitude of about 50,000 feet over the Arizona test area.

FIG. 11. Panoramic rectification (Los Angeles, 1:90,000).

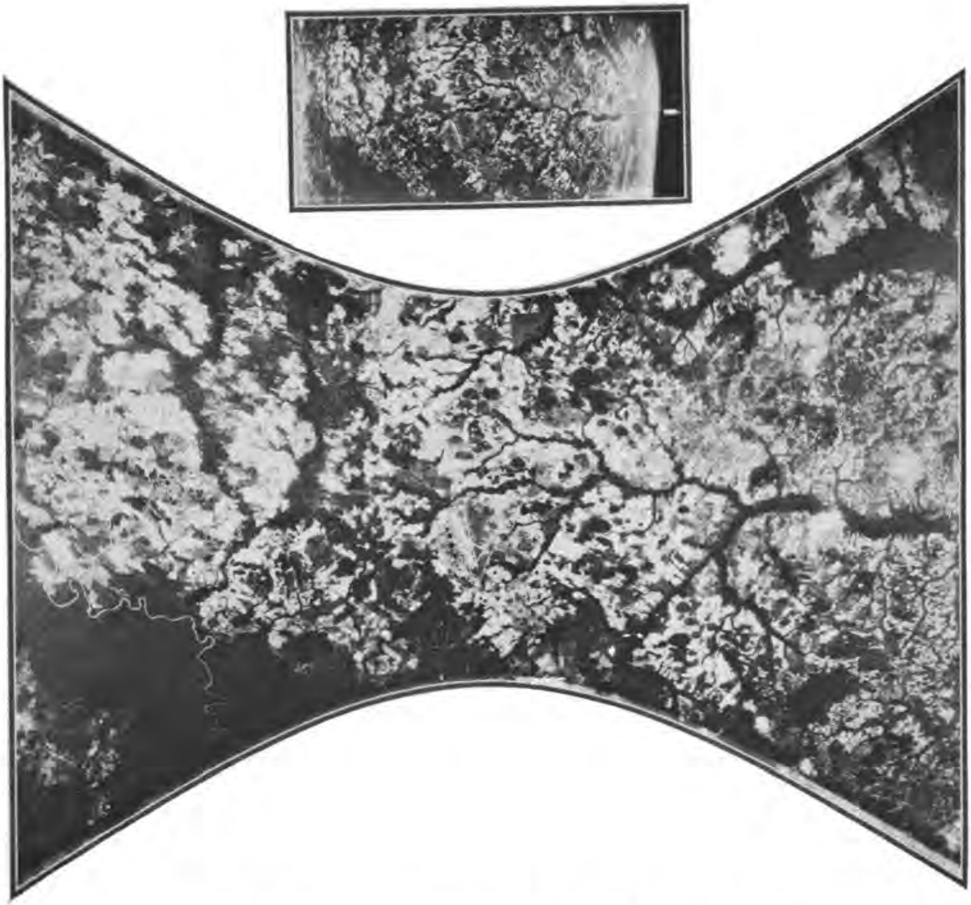

FIG. 12. Panoramic rectification (Shaw AFB, 1:80,000).

A 3-inch focal-length, 70mm vertical panoramic rectification, taken from about 45,000 feet over Los Angeles and rectified at a two time magnification, is depicted in Figure 11. A sweep angle of approximately 140° is shown rectified. Of course, the famous "smog" which appears on the original negative could not be dissipated by the rectifier.

Contrary to popular belief, the use of balloon photography did not cease with the advent of airplanes. Figure 12 is a modern version of "balloon" photography and its rectified counterpart taken from about 40,000 feet with a 3-inch panoramic camera over Shaw AFB, South Carolina. The area covered by the rectified print is approximately 300 square miles.

This Canadian grid (Figure 13) of a 6-inch vertical panoramic photograph, and the resulting rectified squares, show the ability of the instrument to accommodate many focal lengths and formats of panoramic materials. In order to dispel the idea that the new rectifier is a versatile panoramic rectifier only, Figure 14 is a Canadian grid and its rectification of a 6-inch focal-length 60° oblique frame photograph. A real example is illustrated in Figure 15 for a 60°-oblique, 6-inch photograph taken over Arizona. The rectification is at a magnification of 0.5× at the isoline of the photograph of 1× at the principal point. Figure 16 proves the old adage that we can't "go over the hills"; neither can we rectify them in the conventional sense. However, relief distortions are vividly emphasized on the rectified print and detail almost invisible on the contact print can be seen on the rectified print.

The rectification of oblique strip or slit photography cannot be accomplished by any conventional optical projection type rectifiers due to the geometry of this type of photography. In this photography the scale is constant for all lines parallel to the direction of flight,

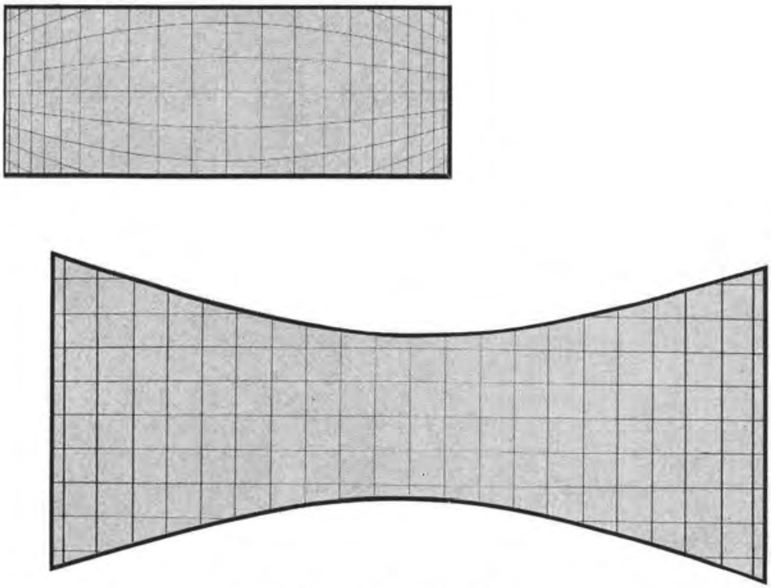

FIG. 13. Vertical panoramic grid.

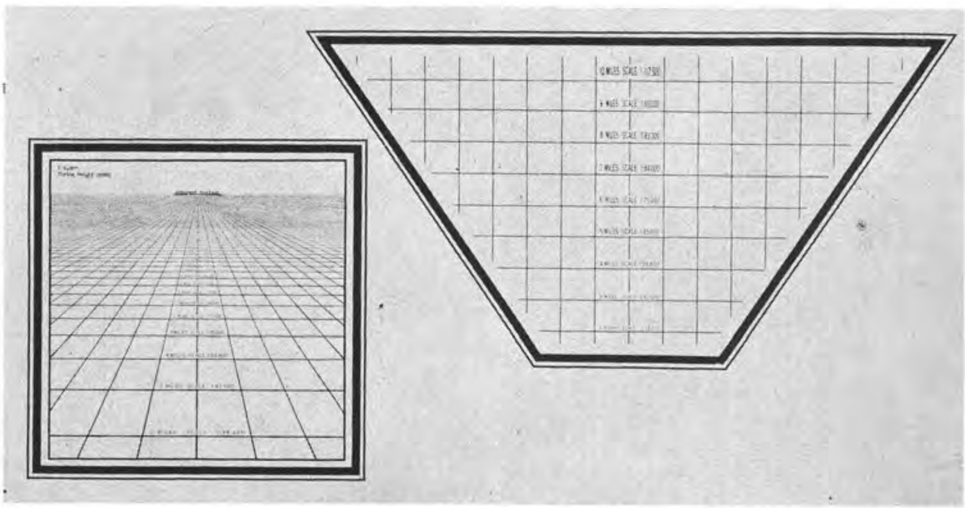

FIG. 14. 60° oblique Canadian grid.

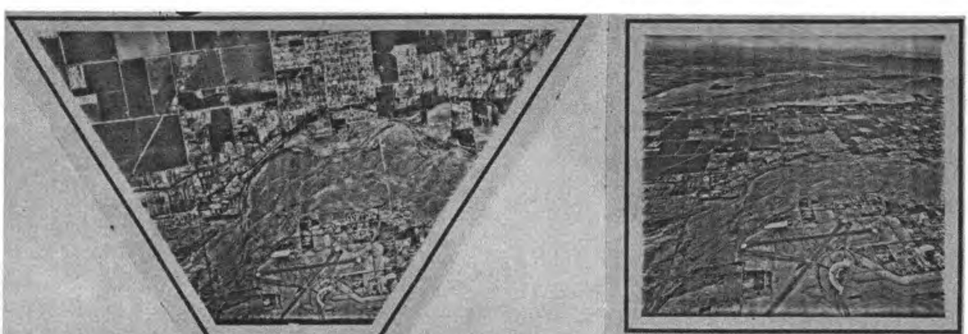

FIG. 15. 60° oblique frame rectification.

FIG. 16. 60° oblique rectification.

and varies in the perpendicular direction. Rectification on the Electro-Optical Rectifier is accomplished by the relative motions between the scanning and recording speeds. Figure 17 shows a 5-mm. square grid rectified with a 30°-oblique strip rectification program. The tilt illustrated is perpendicular to the flight line. Note that the change of scale is in one direction only. A simulation of a 45°-tilted oblique strip photograph is depicted in Figure 18. The fact that the relative speed between the scan of the negative or copy platen and the recording cylinder can be varied presents the possibilities for performing almost any type of affine transformation.

ACIC has been engaged in compiling LAC charts of the moon for the past several years. Rectified images of the lunar surface are required in order to match the detail to the computed positions of existing selenographic control points on the projection used for the charts. Various methods have been used by ACIC to accomplish such rectification (Figure 19). The first part of this illustration shows the parallel projection method which employs a spherical mirror to project parallel light rays from the positive transparency onto a hemisphere. The images on the hemisphere are then copied from the desired angle to produce the rectified negative. Dr. Gerard Kuiper

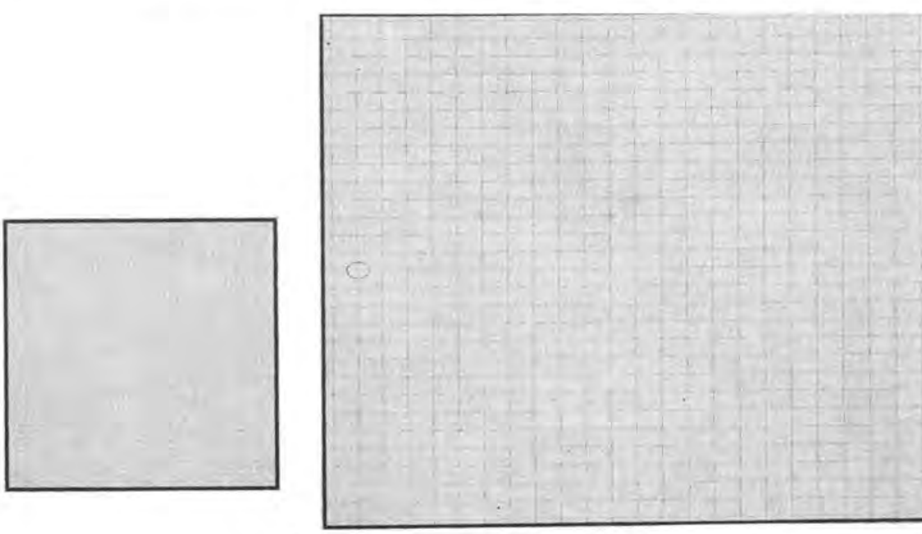

FIG. 17. Oblique strip photography.

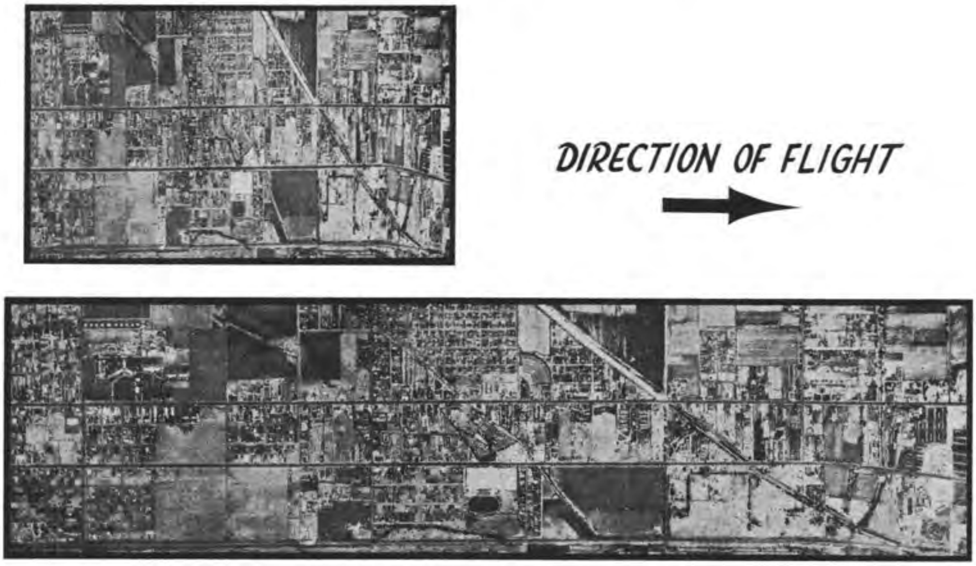

FIG. 18. Simulated strip rectification.

(now at the University of Arizona) and his associates (at the University of Chicago) developed the initial techniques of this method which has since been used with modifications at ACIC. The shadow-casting technique shown on the upper right used a full size negative nearly in contact with the hemisphere. Parallel light rays cast shadows of the image onto the hemisphere which were likewise copied at the required angle. Another procedure employed was to fabricate lunar cones for various angles and to copy the cones with a copy camera. The resulting copy was then correct for one particular angle or circle of the cone as is shown. A method often used, but not shown, was to rectify to a tangent

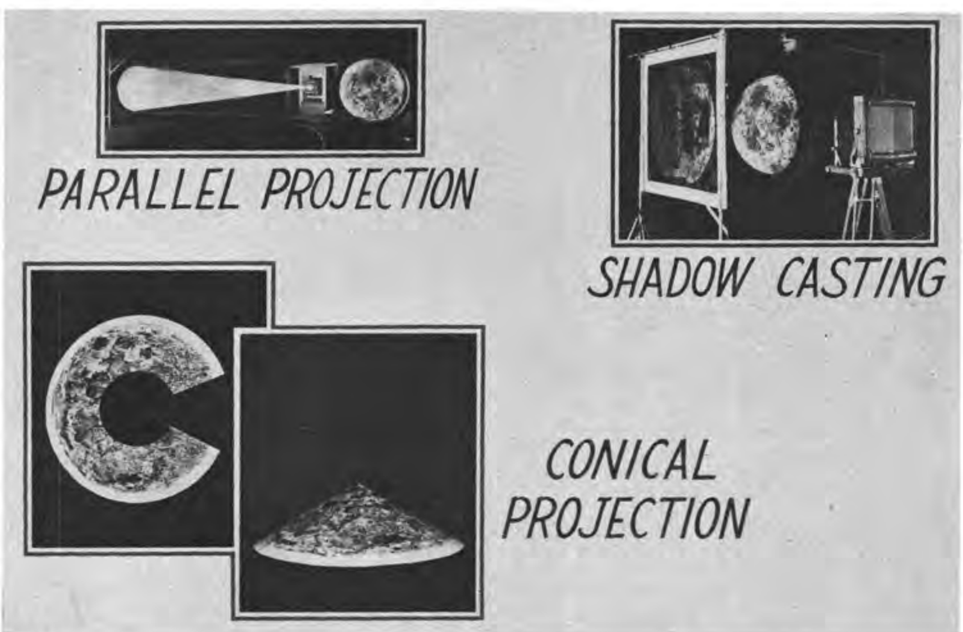

FIG. 19. Conventional methods of lunar rectification.

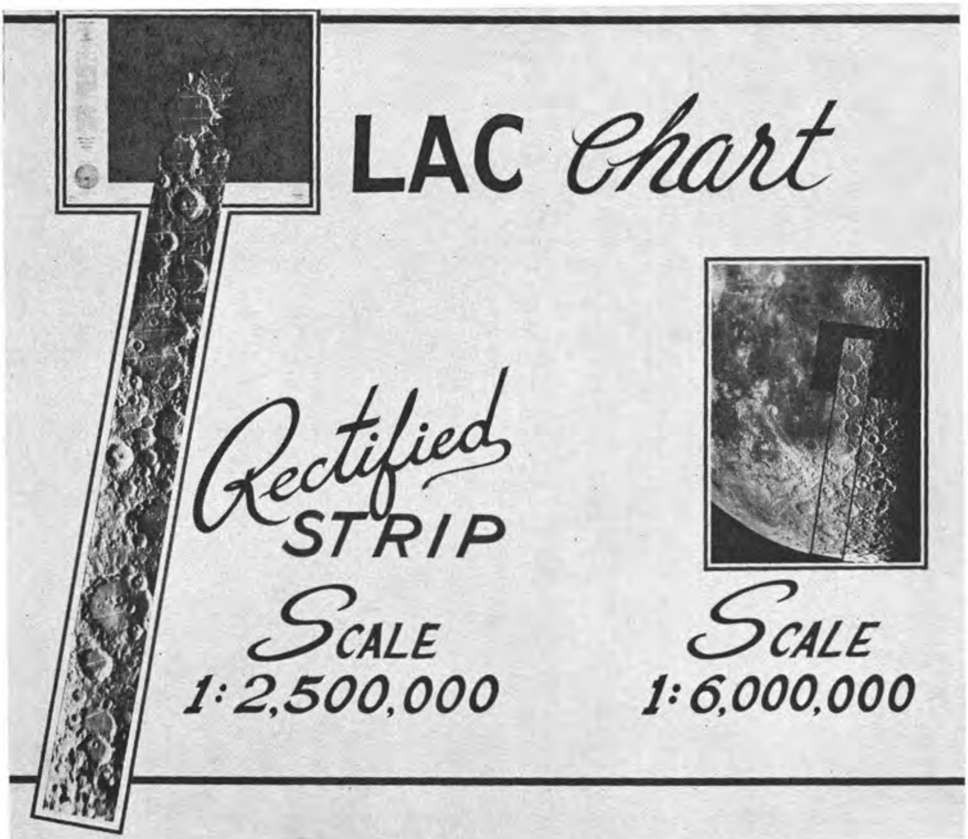

FIG. 20. Lunar strip rectification.

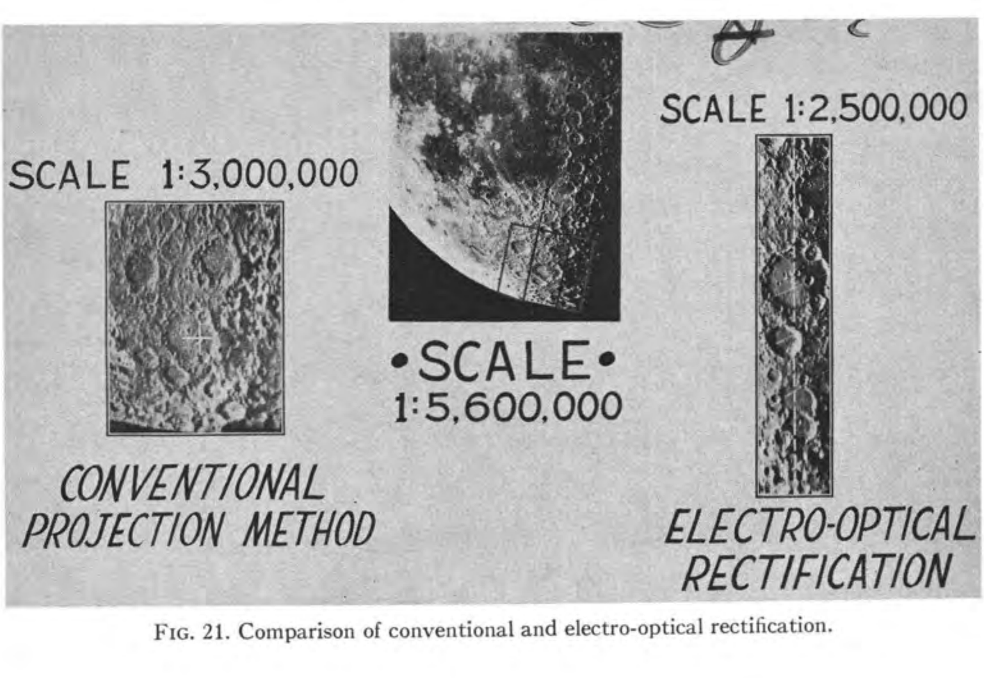

FIG. 21. Comparison of conventional and electro-optical rectification.

FIG. 22. Lunar mosaic, 1:1,000,000.

plane at the center of the desired area with a conventional optical projection type rectifier. This method gave one point where true rectification was achieved. Use of a curved easel offered a larger effective area.

The electro-optical rectifier, through its capability for independent determinations of the elements of rectification in the two cardinal directions, has made it possible to rectify, at a continuous scale, the entire visible area of the lunar spherical surface to a latitude of 80° in narrow strips. Figure 20 shows such a rectified strip from 0° to 80°. Notice how each of the craters is changed from an ellipse to a circle. The LAC chart is shown to depict the close agreement between the chart and the rectified print. Only one computer tape is required to rectify any area of the moon. The only requirement is for a common diameter of the lunar negative. The azimuth between strips can be changed by any number of degrees to obtain the accuracy required. The improvement of the quality obtained from the rectifier over previous methods is depicted in Figure 21. The old method shown was obtained by the parallel-projection technique and is accurate at the point indicated and the rectified strip is accurate along the line indicated. The grid was superimposed on the lunar negative prior to rectification and could be used to provide additional control for LAC compilation work.

In order to illustrate better the quality and capability of the instrument, this lunar mosaic (Figure 22) centered at approximately 60° from the center of the moon, has been made from 4 overlapping rectified strips with 5°-azimuths, and shows what could be done in a very short time to provide a usable mosaic of the moon.

The examples of products produced by ACIC's new rectifier are but a small sample of its capability. As new focal lengths and formats of photography become available, the use of this equipment will be expanded to meet any anticipated requirements.