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A New Concept in Orthophotography

A new concept in orthophotography is produced in the new Kelsh orthophoto instrument, the K-320 ORTHOSCAN.

ABSTRACT: *A description is given of the new Kelsh orthophoto instrument, the K-320 ORTHOSCAN. This off-line instrument introduces a new concept in orthophotography. Neither the film bed nor the projectors move in Z at any time during the scanning cycle. The model image in conveyed to the film by means of a flexible fiber optic ribbon. Regular 23×23 cm diapositives may be used in the three projectors to produce a full double model orthophoto at a nominal 5× magnification.*

I. HISTORY

THE KELSH INSTRUMENT COMPANY was first introduced to an orthophoto instrument when it was awarded a contract by the U.S. Geological Survey in 1963 to construct T-64 Orthophotoscopes. The Kelsh Company obtained a license from that agency to manufacture the T-64 commercially, and several of these units were built for other customers.

In January of 1969, the Kelsh Instrument Company became a division of Danko Arlington. Interest in orthophotography had been growing during that time, and by reason of its experience, our Kelsh Division found itself being consulted about this interesting new technique. Conferences were held with the U.S. Geological Survey regarding their experience with the T-64, and a lot was learned from those meetings.

The T-64 Orthophotoscope had proven itself to be a reliable instrument over its many years of operation. The capability of this instrument to scan a double model in one setup was considered to be a distinct advantage. Good resolution and the virtual absence of scan lines were characteristic of orthophotos made on the T-64. As a result, these orthophotos were used for a variety of purposes throughout the photogrammetric field.

But the T-64 also had its disadvantages, and the Kelsh Division, as the original manufacturer of this instrument, was in a position to catalog the comments, pro and con, that were received from the field.

As a result, our Kelsh Division was able to draft a set of specifications for a new orthophoto instrument which would overcome the disadvantages of the T-64, and would incorporate new features which were suggested as being desirable by the field.

II. DEVELOPMENT OF THE K-320 ORTHOSCAN

In January of 1971, the Kelsh Division participated in the Orthophoto Workshop which was held in Washington, D.C. At that time, a brief description was given of some of the specifications on our new orthophoto instrument.[1] It was explained that three full sized Kelsh projectors were being utilized, eliminating the need for the reduced size ER-55 diapositive plates that were required by the T-64. It was further announced that a new Kelsh six element lens with a 5× magnification was being incorporated into the center projector. This lens was described as having resolution characteristics which were not only far better than existing Hypergons, but also resolution which was relatively constant over the entire double model surface. It was explained that the new system was being designed to produce color as well as black and white orthophotos. The instrument that was described was later christened the K-320 ORTHOSCAN.

A progress report on the development of

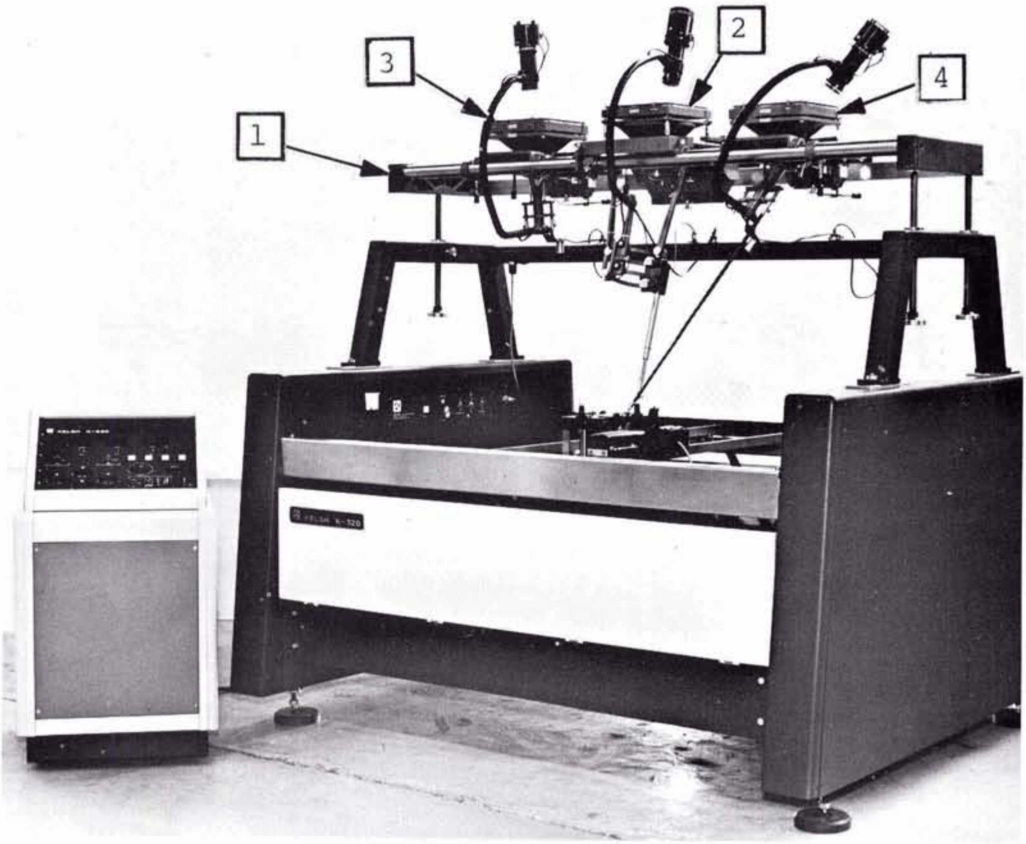

FIG. 1. A front view of the K-320 ORTHOSCAN and its control panel.

the K-320 was given at the Orthophoto Symposium in Paris in October, 1971.[2] At that time, the principle of the fiber optic image conductor was announced and demonstrated.

One of the mechanical problems of projection type orthophoto instruments with smaller magnifications had been the necessity of moving a large and relatively heavy film bed rather quickly in Z. Obviously, the inertia problems to be overcome would have been formidable for moving a 5× magnification film bed.

Our initial experimentation had shown that a flexible fiber optic conductor could be moved in Z very easily, and could convey the image from the model surface to a fixed film bed quite accurately. This particular feature is the heart of the K-320 and is what makes the instrument unique. Both the film bed and the projectors are fixed in position during the scanning. And neither the X nor the Y rails move in the Z direction at any time during the exposure of the orthonegative.

A photograph of the K-320 may be seen in Figure 1. The X bar (Item 1) contains three projectors, all of which accept standard 23×23cm diapositives. Tungsten quartz halogen lamps are used for the projector illumination. The center projector (Item 2) is somewhat larger than the adjacent ones. This center projector contains the six element lens which is used for printing the orthophoto.

The two adjacent projectors (Items 3 and 4) contain standard 5× Hypergon lenses for establishing the stereo on the model.

Referring to Figure 2, the platen assembly (Item 5) is supported on a vertical elevating mechanism which is actuated by a rack (Item 6) and pinion. The drive mechanism for the pinion is contained within a housing (Item 7) known as the "photo head." This photo head is mounted on the Y rails (Item 8 shows one) by means of two linear ball bushings and a roller follower. The Y rail assembly, in turn, is mounted on the X rails (Item 9 shows one)

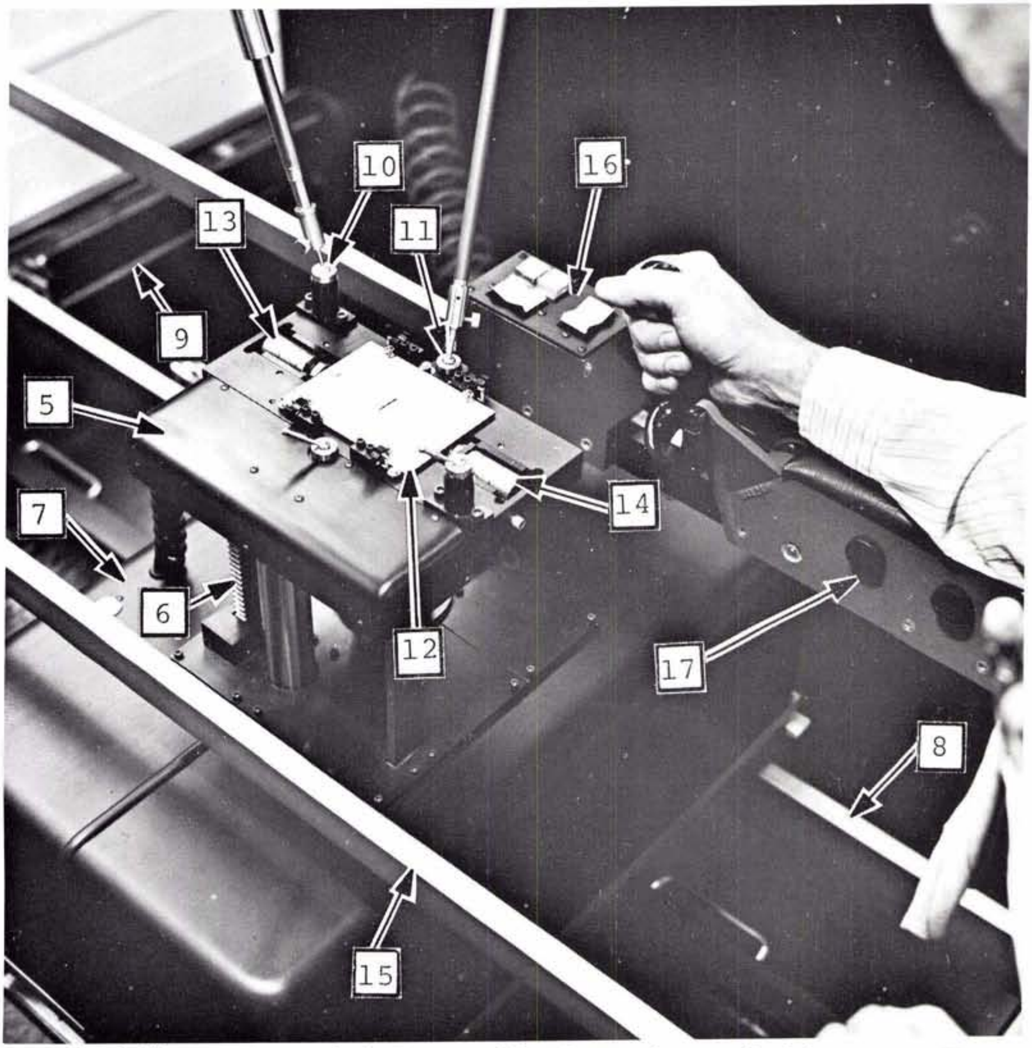

FIG. 2. The operator controls the Z motion of the platen with a joystick while scanning in Y.

in the same manner. This three point contact design assures alignment and stability on both the X and Y rails. Mounting posts (Items 10 and 11) are provided so that the space rods of both the center projector and either adjacent projector will be properly positioned to direct the projector light beams on to the platen.

A shutter (Item 12) is mounted on the platen and contains a slot that limits the size of the projected beam entering the fiber optic image conductor. This shutter is automatically actuated by two solenoids (Items 13 and 14) for an open or closed condition. Shutters with five different slot widths are provided with the K-320. During the operation of the instrument, shutters of *Several* different widths may be used during the printing of *one* orthophoto model.

Figure 3 shows the fixed film bed that is mounted in the lower part of the instrument under the photo head. Flexible Duran curtains protect the unexposed film from any stray light.

The image is conveyed from the slot on the shutter to the film bed by means of the flexible fiber optic ribbon. This ribbon is 2mm wide by 27mm long, permitting a 24mm maximum stepover in X with either a rectangular or parallelogram slot. The fiber optic ribbon itself is 910mm long and is potted in epoxy for about 25mm at both ends at the platen surface and also where it contacts the film. The film end of the ribbon is held very close to the emulsion surface of the film by means of a gimbaled air bearing. This air

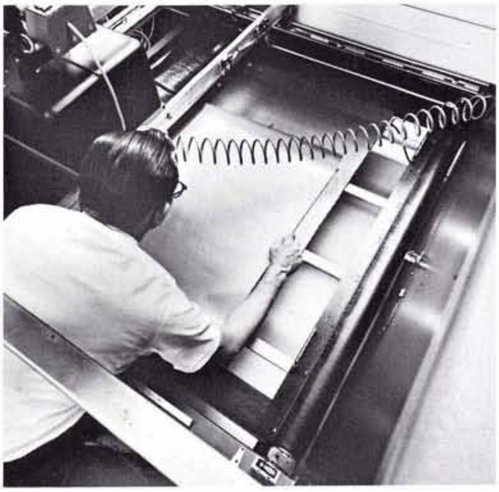

FIG. 3. A view showing the operator placing film on the film bed in the lower part of the ORTHOSCAN.

bearing is permitted to float on its thin layer of air, but is held in rigid orientation in X and Y with the entrance aperture of the fiber optic ribbon on the platen. The fibers between the two epoxied ends of the ribbon are loose. But the entire image conductor is contained within a flexible wire bound tube which has been preformed into an "omega" shape within the photo head.

The air bearing has been designed to be lifted about two inches when film is loaded in the instrument. A small 1.4cfm compressor for activating this air bearing is included as a part of the K-320 system. The film is fastened to the film bed with masking tape. The pressure of the air emitting from the air bearing holds the film flat against the film bed while that particular portion of the film is being printed. This flow of air has an important fringe benefit. It blows away any dust

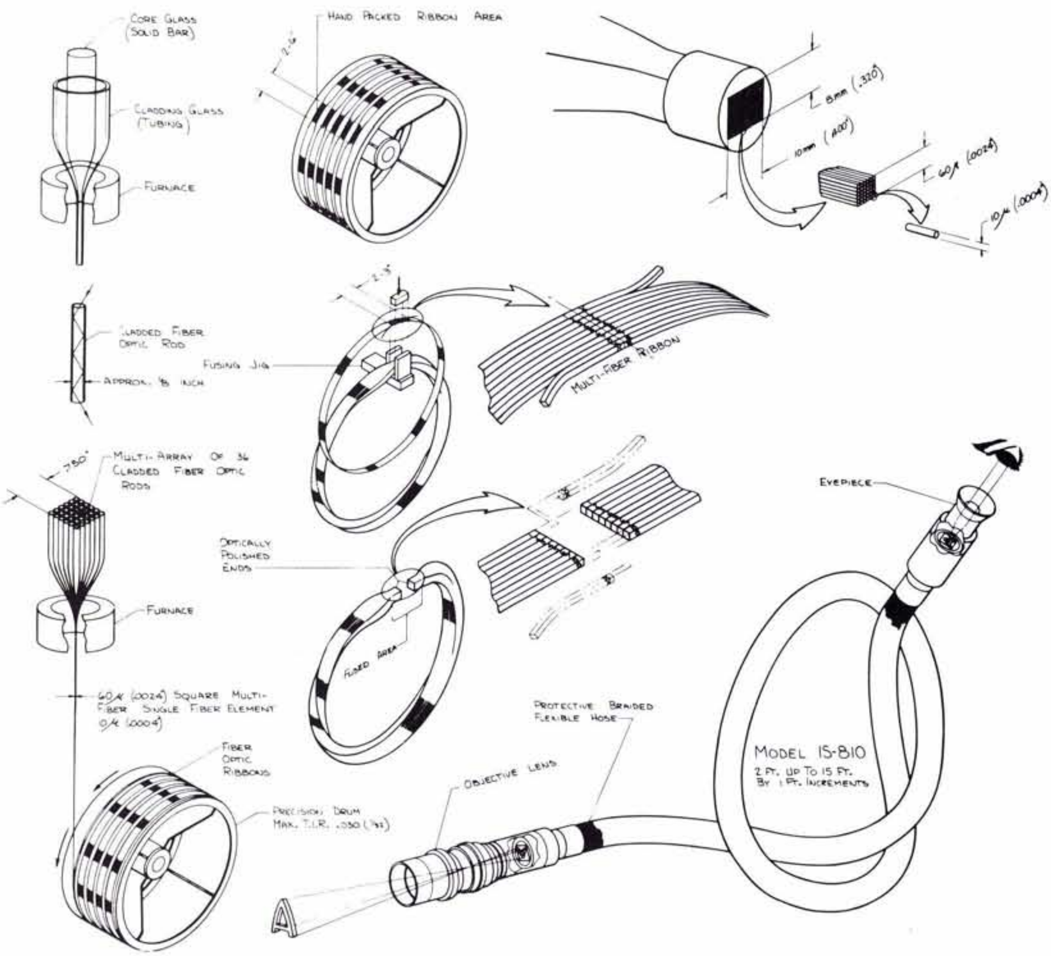

FIG. 4. A schematic description of how coherent flexible fiber optic conductors are manufactured.

or foreign particles from the area being exposed.

In the K-320 system, the platen is stepped over the width of the aperture slot in the X direction, and the scanning is done by the operator in the Y direction.

III. The Fiber Optic Image Conductor

Since the science of fiber optics is relatively new—only about 10 years old—it would be well to describe the construction of our image conductor. The basic fibers used in the conductor are 10 microns in diameter and are laid coherently, 10 microns apart. The individual fibers are made with a core glass cladded with a glass of a lower refractive index. This permits the light to reflect its way through the core fiber by bouncing off the cladding wall of the lower index.

A schematic description of how these fiber optic conductors are produced may be seen in Figure 4. The glass fiber bundles are extremely pliable, and have been flexed several million times without any sign of breaking.

An image which is projected on one end of the image conductor will be transmitted through the fibers to the other end. The transmission loss varies, depending on the type of glass that might be used. However, the fibers that are being used in the K-320 will conduct adequate uniform light for our purposes, at angles in excess of 45° from the vertical. This is quite sufficient for the neat model projection from the 23×23cm diapositive.

The resolution of the image conductor fibers is in the order of 50 line pairs per mm. However, there is a tolerance required in the assembly of the fibers along the axis crossing the 2mm width. Since we are moving the fibers along this axis in the Y direction during tracking, the moving resolution is reduced to about 35 line pairs per mm. This is still better than the center projection lens that is being used in the K-320, and therefore quite adequate for it.

Figure 5 shows a 400× and 1000× magnification of the coherent multifiber sections,

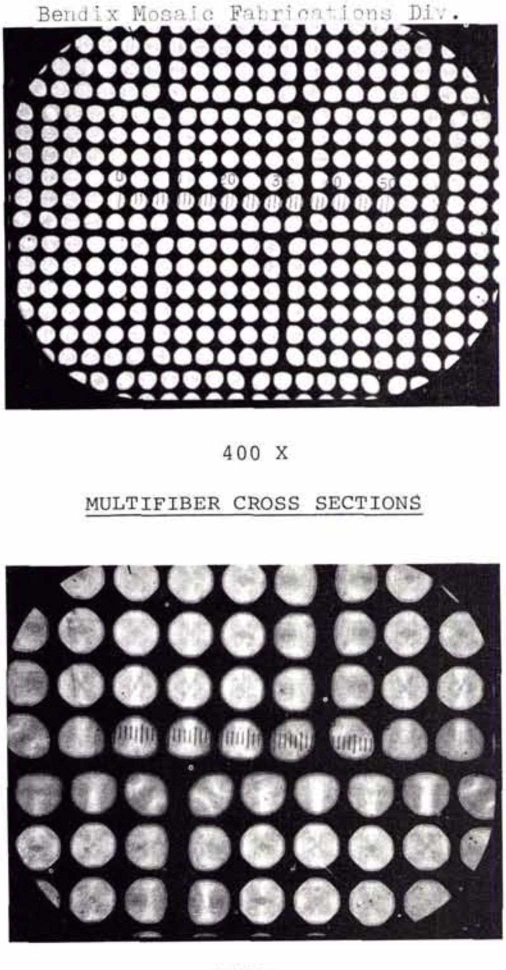

Fig. 5. A cross section of the fiber optics. Each individual fiber is 10 microns in diameter.

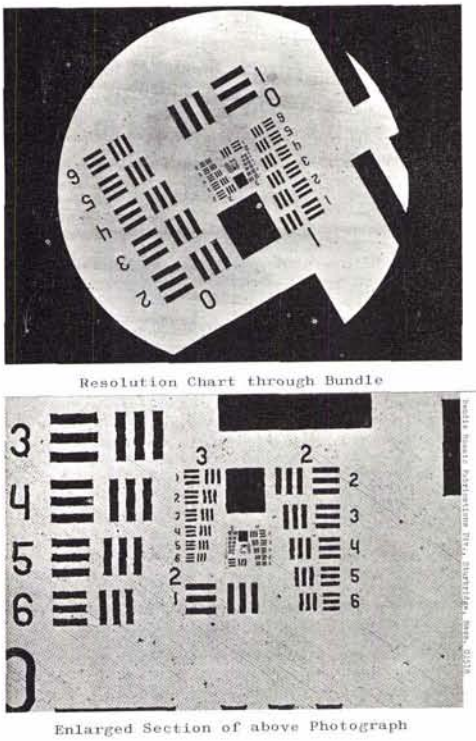

Fig. 6. The basic resolution of the fiber optic conductor is 50 LP/mm.

and Figure 6 shows a projected resolution pattern through these fibers.

It is important to note, however, that the light coming out of the ends of the fibers disperses quite rapidly as shown in Figure 7. The resolution that is captured by the unexposed film will drop quickly as the output end of the fibers is separated from the emulsion surface. Therefore, it is important for the air bearing to float the ground and polished exit end of our ribbon conductor very close to the film. The small separation that is being used for the air bearing gap (about 50μ) will cause a loss of only a few more line pairs per mm. This reduced capacity for film resolution is still better than the resolution which is projected by the six element center lens.

This system has proven to be a most practical way of conveying a faithful image of the projected model to the emulsion surface of the orthonegative. A United States patent[3] has been issued for this method of using a flexible fiber optic image conductor in the K-320 ORTHOSCAN.

IV. Joystick Control and PPV®

The operator of the K-320 uses a "joystick" to control the Z position of the platen when he is scanning in the Y direction. This joystick has been designed for comfort and sensitivity. In Figure 2, the operator is shown grasping the joystick handle. The joystick is mounted on a supporting frame which is carried along with the photo head, but which is separately mounted on its own rails. Therefore, any movement introduced by the operator's hand or arm will not be transmitted to the image platen.

The joystick may be placed on either the right or the left (Item 15) support rail by the operator according to his preference. The handle of the joystick is spring loaded and designed to pivot at the orthopedic center of the wrist. The operator's forearm rests on a cushioned pad to give him a reference base. If the joystick handle is not moved, the platen will track in a level position. Pulling the joystick handle backward or pushing it forward introduces a variable rate and velocity control which moves the platen up or down. During the tracking process, the feel of the joystick to the operator is quite similar to that of flying an aircraft, skimming along the surface of the ground.

Referring again to Figure 2, rocker switch controls (Item 16) on the front of the joystick enable the operator to slew the photo head in X or Y while setting up the model. A rheostat control (Item 17) is also mounted on the joystick to control the intensity of the left or right projector lamp.

A Kelsh PPV stereoviewing system[4] is used for scanning the model on the K-320 in the off-line mode. Figure 8 shows a PPV viewer assembly (Item 18) mounted above the shutter on the platen. Part of the joystick handle (Item 19) is also shown.

In the off-line process, the operator digitizes his scanning in Y while viewing the model in stereo with the PPV system. The surface of the PPV is 31.00mm higher than the fiber optic image conductor. During the playback of the digitized tape, the PPV viewer assembly is removed, and only the center lamp housing is illuminated. The starting position of the platen in Z is then set 31.00mm *higher* than its starting position had been for the digitizing. In this way, during playback, the true model surface will be tracked on the fiber optic conductor through the aperture slot.

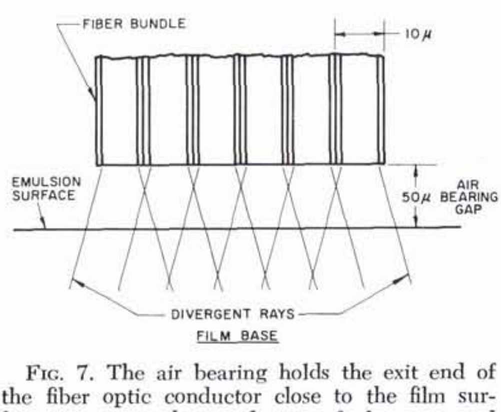

Fig. 7. The air bearing holds the exit end of the fiber optic conductor close to the film surface to retain the resolution of the projected image.

V. Basic Operation of the K-320

The electronic logic for the K-320 ORTHOSCAN has been designed to produce orthophotos up to 1100mm × 1100mm with a nominal 5× magnification. The stepover in X can be dialed to any increment of .025mm up to a width of 24mm. Any of six different scan speeds may be selected for the scanning or exposing in Y. These speeds range from 4 to 24mm per second. The platen has been designed to move a full 250 mm in Z which can accommodate a double model with a great deal of relief. The center projector lens has an excellent depth of field and will project a sharp image throughout the range in Z.

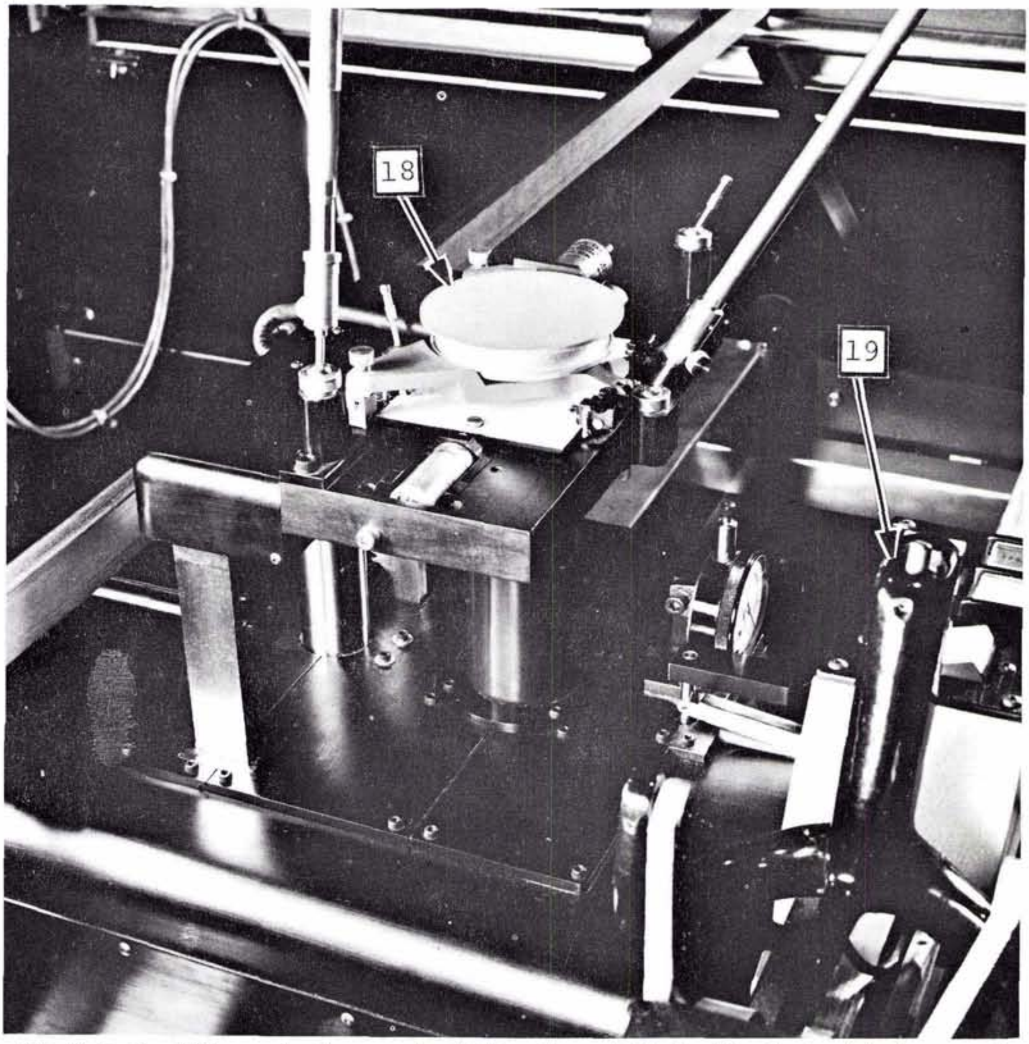

FIG. 8. In the off-line mode, the operator digitizes the model in Y while viewing it in stereo on the PPV platen.

The platen assembly which moves in Z is very light in weight and carefully balanced. Therefore, it can be accelerated or decelerated quite rapidly, providing the operator with the ability to follow slopes up to 70° during tracking.

A shutter cut-off feature has been built into the instrument so that the operator may have the option to scan the front half of a model, and then to go around to the other side of the instrument with the joystick and scan the back half. The shutter cut-off prevents a double exposure along the center line of the film. This is necessary because of the large area that is projected with the 5× magnification. However, any rectangular area can be scanned from one side by the operator in the "single scan" mode.

The K-320 has been designed to be used as either an Off-line system with digitized tape, or as an on-line unit with the use of anaglyph filters. Since the introduction of this new instrument, the great deal of interest that has been shown in the off-line system makes it unlikely that it would be used extensively in production as an on-line unit. However, it has that capability, if required.

The K-320 projector lenses have been designed for a nominal 5× magnification for 153mm photography with analog in X, Y and Z. Other photography such as 305mm and 210mm may be used in the K-320 for orthophotography as long as the photography is reasonably level. In the latter two cases, the

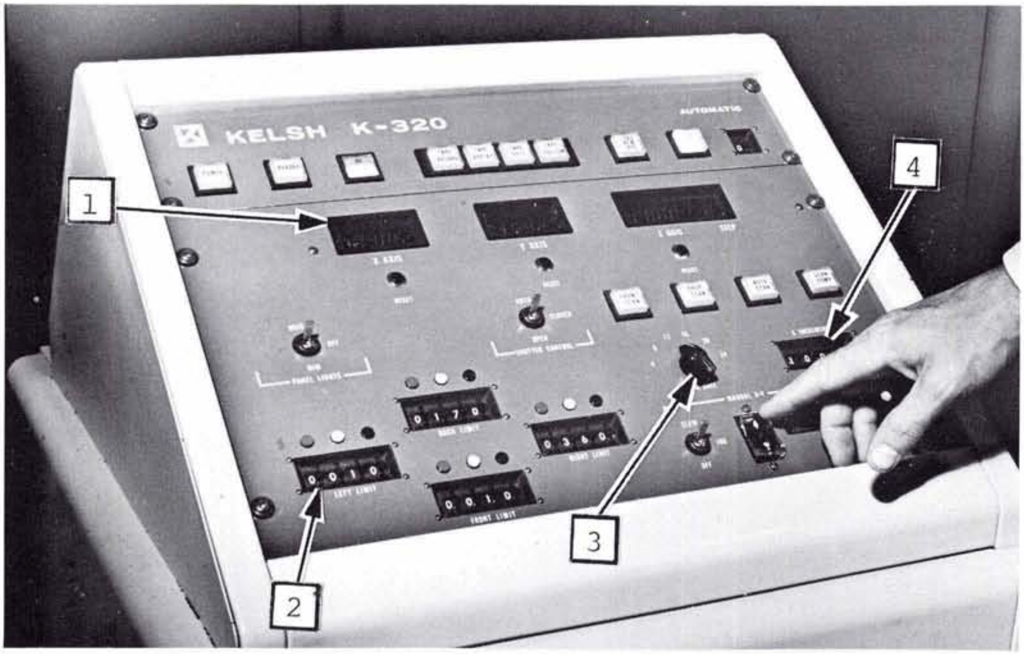

FIG. 9. The panel of the control console showing the Panaplex readouts, the limit switch settings and the selector switch for tracking speeds.

Z appears less than scale in the model, but the imagery is projected in true X and Y positions on the orthophotograph.*

Figure 9 shows the panel of the control console. The K-320 is a metric instrument, with all indicating digits in millimeters. A Panaplex readout (Item 1) is provided for the X, Y and Z positions of the platen. In the lower left corner of the panel are located four limit switch dials (Item 2). With these dials, the operator may select any rectangular area that he wishes to cover with his scanning. The scan rate switch (Item 3) gives him the choice of the six different scan speeds. The X increment stepover dial (Item 4) may be set for any shutter width up to 24mm.†

VI. Automatic or Off-Line Tracking

The automatic system of the K-320 permits the operator to scan the model with the PPV, in black and white or in color, without any film in the film bed. A position in Z is recorded during each scan for every 1.6mm in Y. This information is stored in a memory and does not have to be permanently punched out on the tape by the operator until he is satisfied with it. The operator can backtrack the scan through the memory so that he can see how well he followed it. He then has the choice of saving that scan, or completely erasing it and doing it over again. Also, when he reaches a particularly difficult section of the model, he can scan the terrain as slowly as he wishes to be sure of his accuracy. He can go across lakes and flat areas at a faster rate if he so chooses.

In the original design of the K-320, an "Edit" mode had been incorporated so that an operator could add or subtract a ΔZ value from a scan that he had made while that scan was being examined. This proved to be impractical in the field because the operator had to wait until the *instrument* reacted before *he* reacted, and then it was too late to make a good correction. So an improvement was made to give the operator the ability to either completely *erase* the scan and do it over again, or to *save* the scan that he had previously made.

After the operator has generated a tape for the model that he has scanned, he may place unexposed film in the film bed and play back the tape with just the center projector illuminated. The orthophoto would then be printed with the white light of the center projector in either color or black and white. The K-320 interpolates the incremental Z information of the tape during playback, and produces a smooth curve in Y when either climbing up or going down a slope.

While the tape is printing the film in the

* † See footnotes on page 1170.

ORTHOSCAN, the operator may remain in the same room with his desk lamp illuminated, and compute his parameters for the scaling of the next model. The fiber optic conductor will not accept light from angles much beyond those of the projected image.

With the automatic system, a skilled compiler may produce a full double model orthophoto on tape and record the absolute orientation points of the center projector. At a later time, perhaps on the night shift, a less skilled operator could replace the diapositive on the center projector, position it to the absolute orientation points, and print the orthophoto from the tape. The off-line method, of course, has many advantages, such as being able to print a film a second time if the original negative was not developed properly. Also, the tape may be digitized at either one or several different speeds, but it should be played back at just one speed during the printing process.

VII. Conclusion

There are a number of obvious advantages to the K-320 ORTHOSCAN system. The

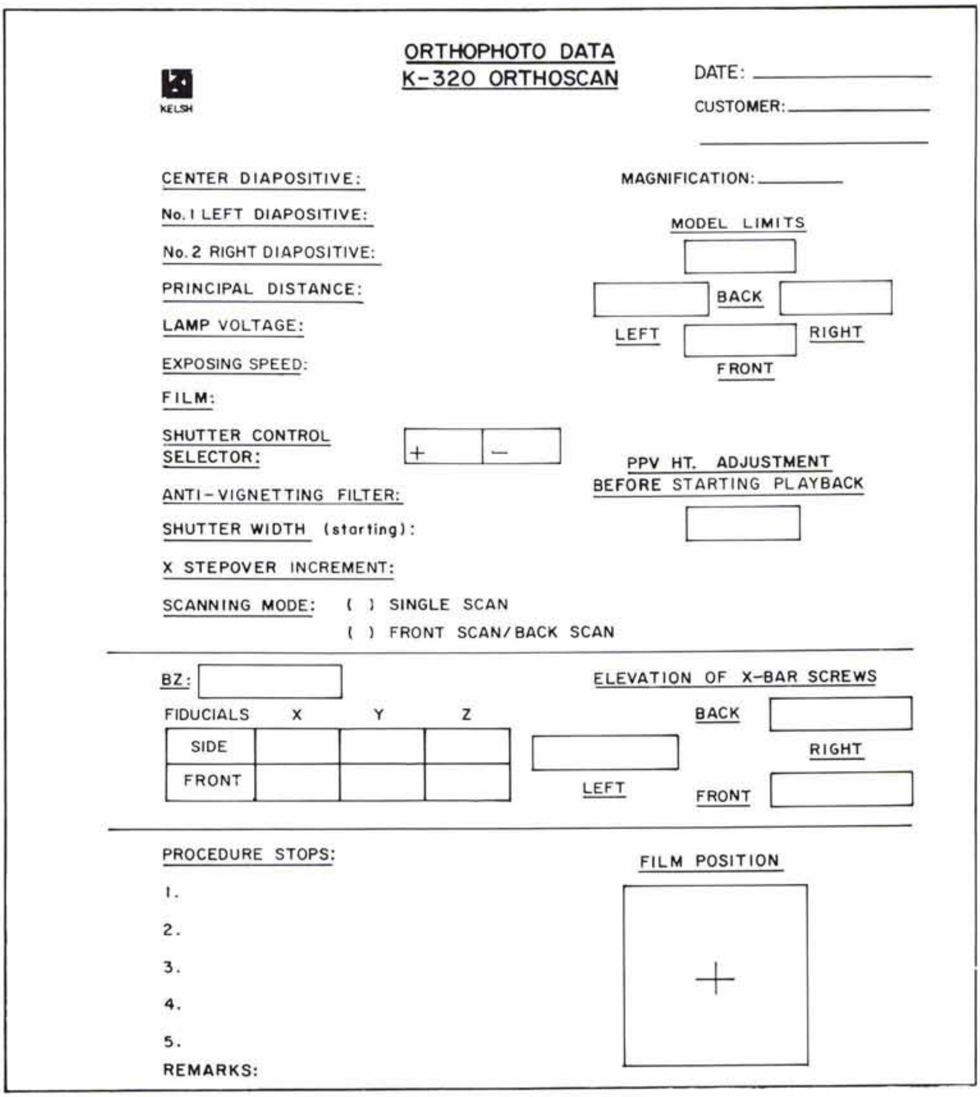

Fig. 10. A procedural form for recording set-up parameters, the scanning procedure and absolute orientation positions.

fiber optic image conductor solves many problems and makes a simple yet highly accurate instrument practical.

With the regular 23×23cm diapositives, the K-320 may be set up about as quickly as a standard Kelsh plotter. The operator has finger tip control of the slewing motions in X, Y and Z during set up. Of more importance is the fact that he may scale the model directly on the instrument at a nominal 5× magnification—and that the resulting orthonegative can fulfill National Map Accuracy Standards.

The shutter width may be changed, if desired, at any time during the scanning of the model. By the use of the standard PROCEDURE STOP switch, the operator can go from a wide shutter to a more narrow one for rougher country, and then change back to a wide shutter again if he so wishes. During playback, the PROCEDURE STOP instructions on the tape will stop the instrument at the end of a scan, and allow the operator to make such shutter changes and X stepover alterations.

A procedural form is shown as Figure 10, which may be used by the operator for recording the scanning information. This form is a record of the compiler's set-up, scanning procedure and absolute orientation positions. It may be kept with the tape and referred to at any time in the future for reprinting the same orthophoto.

With the tape that is generated from the off-line scanning, and the proper software, contours can be traced at desired contour intervals when the tape is interfaced with automatic plotting units. The resolution of the contouring, of course, would be a function of the scan width and the accuracy of the scanning by the operator.

This process can be reversed, too. Contouring which is digitized on a data grid with a stereoplotter may be used for the K-320 input. With the proper software and a computer, such information may be transformed into Y-scans at the proper X-stepover increment. Since the K-320 is a digital instrument, this information can be fed into the ORTHOSCAN reader to print the orthophoto.

The K-320 uses standard process film. Such film can be developed and dried in the latest commercial processing machines in about 75 seconds.

The joystick provides a bit of human engineering which makes the scanning process far less tedious for the operator. The ability to erase or retrack any scan eliminates the strain of plotting directly on unexposed film. And the off-line system permits the production of color orthophotography.

We at Kelsh are quite excited at the future prospects of orthophotography in many different applications. It is the opinion of our people that the K-320 ORTHOSCAN will have an important place in this new and most promising field of photogrammetry.

References

1. Danko, Joseph O. Jr. "The Kelsh T-64 orthophotoscope" presented at the Orthophoto Workshop, Washington, D.C., January 1971.
2. Danko, Joseph O. Jr. "The Kelsh K-320 ORTHOSCAN—A New Concept in Orthophotography." Presented at the IGN Orthophoto Symposium, Paris, October 1971.
3. United States Patent No. 3,694,072 to Joseph O. Danko, Jr., et al, issued September 26, 1972.
4. Danko, Joseph O. Jr. "Color, the Kelsh and the PPV" published in the January 1972 issue of *Photogrammetric Engineering*.

Acknowledgement

Figures 4, 5 and 6 are through the courtesy of the Bendix Electro Optics Division, Sturbridge, Mass.

* Modifications have since been made to permit also the production of orthonegatives in the 4× range.

† The fan-folded tape punch and reader (Item 5) is positioned below the panel.

Where to Get ERTS Imagery

To inquire about obtaining ERTS imagery, write to EROS Data Center, Data Management Center, Sioux Falls, South Dakota 57198. The telephone number is 605-339-2270 and the phones are staffed from 7 a.m. to 7 p.m., Central Time. Details are contained in a brochure, "The EROS Data Center", U. S. Geological Survey, Washington, D. C. 20006, as well as from many other USGS offices.