*Let's Go Over the Hill**

Potential Benefits of Profile Scanning the Stereo-Model

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ABSTRACT: *This paper reports initial work performed at the Army Map Service on a study that seeks to determine the practicality and potentials of profile scanning the stereo-models as a means of compiling topographic maps, master terrain models and allied products.*

The study advances four objectives to be realized by the act of scanning. These are: the extraction of contour information; development of orthographically restituted imagery; recording and storage of profiles scanned; and the construction of master terrain models from the profiles scanned. Several instrumental means for accomplishing these four objectives are discussed.

This photogrammetric departure is concluded to be meritorious since, by the system proposed, a greater number of stereo-models would be processed by any given photogrammetric facility, savings in elapsed time for map compilation would be realized and appreciable savings in time and money for master terrain model construction would accrue.

Although as of this writing, the merits of this integrated mapping system have not been verified completely, and requisite instrumental means have not been perfected, disclosure of this system is believed warranted in the hope that other contributions toward efficient profiling instrumentation will be forthcoming.

I. INTRODUCTION

TO MAP PRODUCTION ENGINEERS, the elapsed time between beginning stereo-map compilation and delivering the printed map edition is a matter of constant concern. Certain of the stations within the map production stream contribute heavily to the protracted elapsed time presently required. The fact that current stereo-compilation operations fall in this category becomes evident when these procedures are analyzed. The essential disadvantage of present practice, it would seem, is the very fact that compilation must, of necessity, be accomplished under stereo-plotting equipment. This stems from the fact that we do not have complete instrumental means for preserving or recording the stereo-model in convenient form, so that compilation can be executed in locations removed from the stereo-booth. Such being the case, the plotting instrument is not utilized full time in *plotting* terrain. Instead, up to 50 per cent of the operator's time is spent in *compiling* a manuscript from the projected imagery. In the latter task, interpretation and other judgments demanded of the compiler make necessary procedures whereby the topographic and cultural features are intensified and reshaped in pencil prior to inking or scribing the stereo-compilation. These procedures, furthermore, give rise to variations in expressing the terrain by operators compiling contiguous areas. Variations in compilers' work are made constant only through rather constant supervision.

To accomplish stereo-compilation, by the present procedures, an expensive instrument is required, operated by an individual possessing keen visual acuity, well trained in orienting photography and in maintaining his instrument, and who, in addition, must be a reasonably accomplished draftsman and an experienced photo-interpreter and topographer. The capacity of a base plant to produce new map compilations is, therefore, dependent upon the number of precise stereo-plotting instruments and highly trained stereo-

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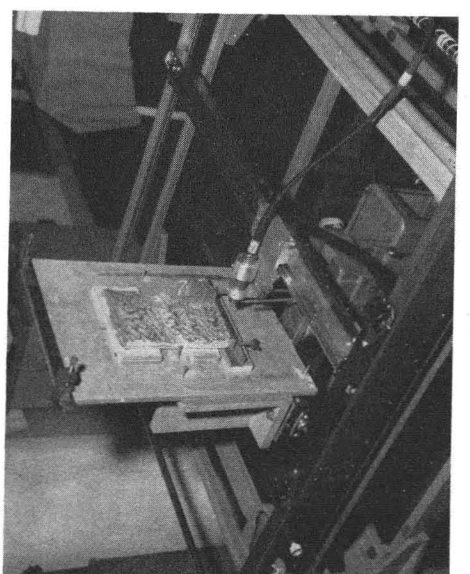
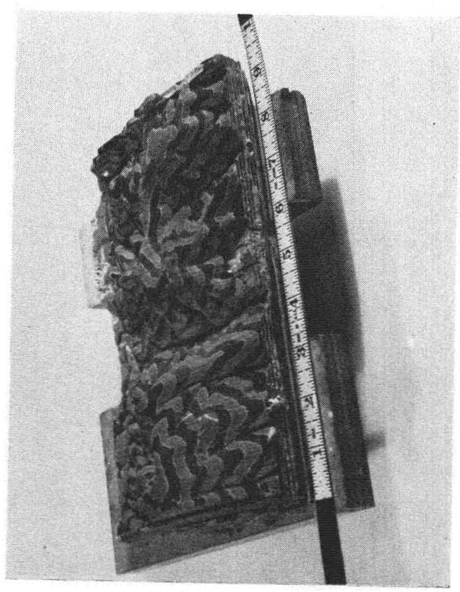
operator-compilers available. Elapsed time for this phase is appreciable, and no subsequent operation in the production stream can begin until the produce from a single stereo-compiler is released.

In an effort to devise a more efficient system, a detailed study of certain works which employ profile scanning was undertaken by the authors. The potential of profile scanning the stereo-model, as a direct means of producing large-scale master terrain models, was convincingly established by experiments conducted by the Relief Map and Photogrammetric Divisions of the Army Map Service (reference 1). In this work, a Wild A-5 instrument was so modified as to permit a block of laminated wax sheets to be routed coincidentally to the act of scanning the stereo-model. Through Bench camera photography of the resulting terrain model, an orthographic image was obtained, from which contour data could be easily extracted (Figures 1 and 2). A contemporary development, the Orthophotoscope, as reported by Russell Bean (reference 2) was also studied, as was the earlier work on a photorestitution machine by Gallus and

VIEW A



VIEW B



VIEW C

FIG. 1. Cutting terrain model by direct linkage with a Wild A-5. View A shows block of laminated sheet uncut in the upper righthand corner, rough cut in the lower righthand corner and finally cut on the lefthand side of this view. View B shows model erected on modified Wild A-5 Coordinatograph table. View C shows the finished model. Note alternate contour bands developed by profiling.

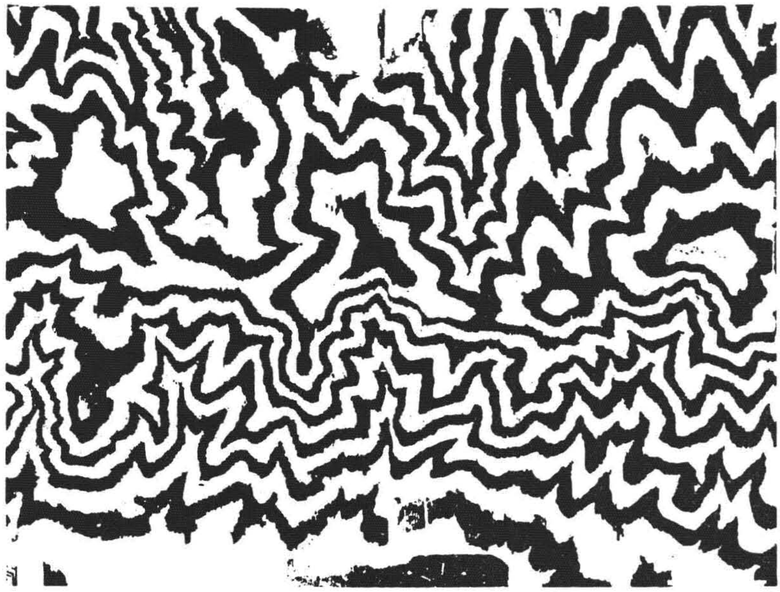


FIG. 2. Orthographic photograph of model shown in Figure 1. The serrations appearing in this enlarged photograph denote consistency with which the instrument operator was able to develop contour location by successive profile scans. This restituted imagery could serve as scribe guide copy for the scribing of the contour separation.

Ferber (reference 3). These techniques provide means of converting conventional perspective photography to the equivalent of orthographic imagery. This is a major advancement, for it enables the stereo or spatial model to be transformed and preserved in convenient form. The work of Richard Ray (reference 4) was also scrutinized, for his simple technique of drawing in profile, coincident to the act of scanning the stereo-model, provides a means of recording and storing the stereo-model in still another convenient form.

Based upon the literature cited above, and other experiments conducted at the Army Map Service, scanning the stereo-model in profile appears to be potentially attractive if the scanning operation itself is a practical exercise. The following is a report on a preliminary investigation in this area.

II. Indicated Advantages of Profile Scanning the Stereo-Model

In evaluating the work performed by the Relief Map and Photogrammetric Divisions, and reported in reference 1, the following merits of scanning and recording profiles from the stereo-model were indicated:

a. The scanning operation was found to be quite straightforward. Operators performing initial tests expressed their opinions that profiling consumed no more time per model than if they had plotted contours by the conventional methods. They ventured, furthermore, that if they had had as many years of experience in profiling as they had in contouring the stereo-model, profiling would prove the more rapid.

b. Because of the straightforwardness of profile scanning, and since compilation processes were not involved, operators conducting initial tests expressed the opinion that competent operators could be trained in less time than presently required to indoctrinate and train instrument compilers.

c. Initial tests of cutting profiles into a block of wax, composed of laminates of alternating colors, revealed great consistency in developing the position of each contour by this indirect technique (Figure 2). This should be expected, since profiles were scanned at intervals of .025 of an inch. A contour lying perpendicular to the direction of scan was crossed 40 times per inch. These multiple line crossings, therefore, strengthen the position of the contour developed. From this, one would not expect to see great variations in contour detail by two or more instrument operators profiling contiguous areas.

d. Since profile carving into a block of wax, composed of layers equivalent in thickness to the desired contour interval, affords visible evidence of the ability of the operator to consistently "keep the dot on the ground," supervision of this effort would be less than demanded by present procedures.
e. Profile scanning, for all practical purposes, results in the operator scanning the stereo-model 100 per cent. Thus, island contours need not be searched, nor are they likely to be missed.
f. Greater quantitative terrain information is developed through profiling with the attendant advantage in regard to producing three-dimensional plastic reproductions and to problems associated with selecting, judiciously, supplementary contours for the topographic map edition.

III. Indicated Disadvantages of Profile Scanning of the Stereo-Model

Profile scanning of the stereo-model is not without certain disadvantages. These must be considered before the scanning approach can be declared superior to conventional stereo-plotting techniques. Some apparent disadvantages are:

a. Contour identification and spot heights are not immediately developed by the scanning of profiles, and unless orthographic capability is synchronized with the act of scanning, material required for compiling cultural detail is not gained.
b. Profiling, initially at least, would prove somewhat foreign to presently trained stereo-instrument operators. To indoctrinate operators in the new procedure would require a training program.
c. The system proposed in this study, discussed in detail later in this report, suggests that compilation can be accomplished by personnel other than the stereo-instrument operator. This implies that the instrument operator is free to spend full time on profile scanning. Since scanning would be repetitious, job boredom could become a greater problem to operating photogrammetrists.
d. Instrumentation costs for profile scanning would be high; probably higher, in fact, if orthographic capability should be introduced into present equipment.
e. Demands for dimensionally stable materials, for association with instrumentation to record the profiles scanned, would be stringent.

IV. Objectives of a Map Production System Based upon Profile Scanning

Based upon the disadvantages associated with the present stereocompilation practices, and mindful of the apparent advantages of profile scanning the stereo-model, an attempt has been made to advance an integrated map production system, the merits of which may outweigh the related disadvantages. The objectives of this system are to provide the following information as the direct result of a *single* photogrammetric plotting operation, or to enable such to be gained rapidly by other optical, mechanical or electronic means, at locations removed from the plotting booth:

a. Information from which contours may be quickly and accurately scribed by personnel other than the photogrammetric instrument operator.
b. Restituted photography of the projected spatial model for use as:
   (1) Material for photomap production.
   (2) Material for photomap back-ups for the topographic map edition.
   (3) Orthographic material from which requisite color separation negatives can be prepared.
   (4) Imagery for molded photomap production.
c. Terrain data, so stored as to permit automatic or semiautomatic manipulation to yield map and model products at smaller scales.
d. A three-dimensional model at conventional large scale publication scales; i.e., 1:25,000, 1:50,000 or 1:100,000.
e. From the foregoing three-dimensional model, to extract by photomechanical means:
   (1) Shaded relief overprints for flat maps.

(2) Open window negatives for layer or gradient tints.
(3) Special model views.
(4) Contour data for flat map edition.

V. Suggested System to Satisfy Objectives

Figure 3 portrays, diagrammatically, the suggested integrated mapping system. The focal point is shown at letter *A*, which conveys profile scanning of the stereo-model. During this operation, the "*X*" motion on the stereo-plotting instrument used, i.e., Kelsh, Balplex, Multiplex, etc., would have to be fixed for progressive scanning at a set interval, depending on the map detail and scale involved. The "*Y*" (horizontal) direction could be controlled by a left handwheel, while the "*Z*" (vertical) motion is manipulated by a right handwheel. The rate of travel in the "*Y*" direction should, preferably, not be fixed in order to permit the operator to vary his rate of scanning as

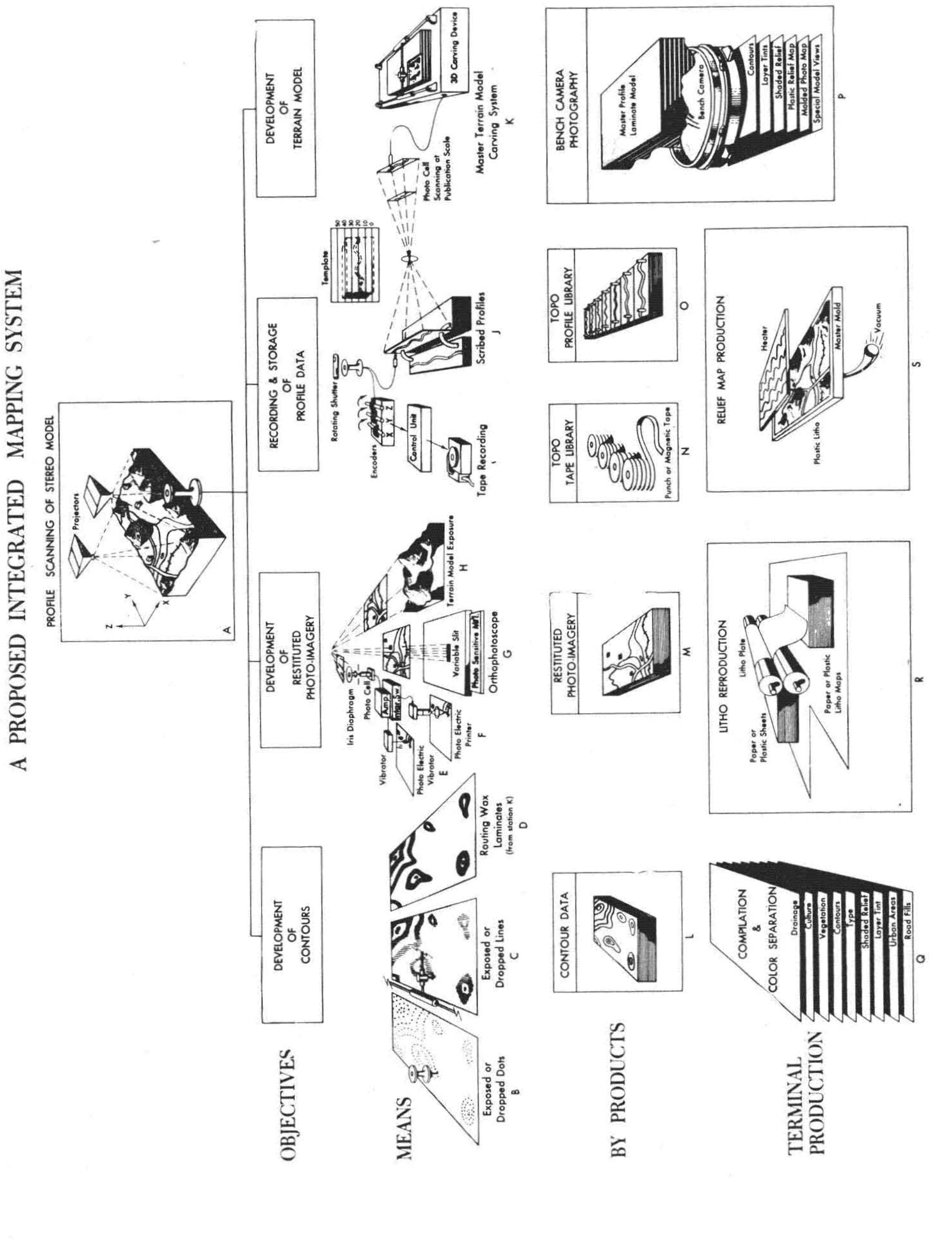


FIG. 3. Diagrammatic presentation of the proposed integrated mapping system, based upon profile scanning the stereo-model.

dictated by the relief encountered.

Scanning can be accomplished in either the "X" or "Y" direction to take advantage of the terrain formation. Initial AMS tests of this procedure were conducted on the Wild A-5. In normal operation of this instrument, lead screw connectors from the right handwheel control the "Y" axis motion, while the foot wheel controls the motion of the "Z" axis. These connectors were reversed to effect an exchange of gear train motion, thereby producing "Y" motion in the foot wheel and "Z" motion in the right handwheel. After lowering the floating mark "onto the ground" by means of the right handwheel, the operator traversed along the "X" axis by rotating the left handwheel, continuing to maintain floating mark-ground contact throughout the distance of the "X" axis traversed. This coordinated right and left handwheel motion produced, in the "X" and "Z" axes, a profile slice, the "Y" increment of which was established by the diameter of the cutting blade tip. Cutting of the scanned profiles in the block of laminated wax sheets was accomplished by an independently mounted Miller #40 grinder, employing a cutting blade made from a 3/16-inch shank diameter (Figure 1).

In order to accommodate profile scanning by the Multiplex, Balplex or Kelsh plotters, it would be necessary to fabricate a mechanical "X"-"Y"-"Z" guiding system to fit onto the plotting tables, possibly along the lines of the Nistri Photocartograph.

Adoption of a universal steering wheel device similar to the Veltropolo in the Nistri Photostereograph, Model BETA/2, for controlling the motion of the floating mark, should reduce the skill required by the operator to scan successive profiles. Operator fatigue would also be minimized.

As shown by Figure 3, profile scanning is envisioned to yield material required to satisfy the objectives of developing contour information, restituted imagery, recording and storage of the profile scanned and constructing master terrain models. Several means of realizing these objectives have been considered thus far in this preliminary investigation. They include the following:

a. DEVELOPMENT OF CONTOUR INFORMATION

(1) *By dropped or exposed dots and lines*

These suggestions are illustrated at letters B and C in Figure 3. Envisioned here is a mechanism whereby dots or lines could be dropped or exposed at predetermined elevations based upon the contour interval selected and keyed to enable the compiler to recognize readily the proper values for each dotted contour so developed.

The dropped or exposed lines shown at letter C would result if a stylus or pencil could be locked in with the handwheel controlling the "Y" motion so that lines could be exposed or scribed for alternate contour elevations. For example, if a 10-foot contour interval is selected, readouts would be made only at values ranging between 0–10 feet, 20–30 feet, 40–50 feet, etc. By skipping every 10 units, no lines would appear for elevations ranging from 10–20 feet, 30–40 feet, etc., thereby alternate contour bands would be developed. Two methods are suggested for developing these contours by the "drop" technique:

(a) By the use of a coordinatograph attachment to drop or scribe dots or lines.

(b) By exposing a light source onto a photo-sensitive material to expose the dropped dots or lines.

(2) *By routing wax laminates*

Reference 1 discloses the means of developing contours by profile carving into a block of wax, composed of laminates of alternating colors, the thickness of each corresponding to the selected contour interval. Should terrain model production be contemplated at the time of initiating photogrammetric operations, this procedure would probably be the correct one for gaining the contour data. In this instance, profiles shown as developed at letter J would be employed to activate the three-dimensional coordinatograph shown at letter K. Further details on this procedure appear later.

b. DEVELOPMENT OF RESTITUTED IMAGERY

(1) *Photo-electric vibrator* (letter E in Figure 3)

This system produces halftone images from an engraved plastic material. The German "Klischograph" and the American "Scan-a-Sizer" are examples of such a system and both are in practical and successful operation. These systems suggest the possibility of placing a photo-electric cell beneath the tracing table and having it focus on the open window of the platen.

The photo-electric cell would collect and measure the light projected from the stereo-projection system and feed it through an amplifying circuit into a vibrator, which would cause a cutting stylus or chisel to engrave a plastic sheet from which an orthographic halftone image is produced.

(2) *Photo-electric printing* (letter *F* in Figure 3)

The same type of scanning technique would be used in this system as is visualized for the photo-electric vibrator system, except that instead of using a vibrating tool, the restituted imagery would be obtained by projecting a modulated light source onto a photo-sensitive film. A light integrating switch would be used to control the exposure level.

Improved print quality might be achieved by processing the stereo-photogrammetric diapositives through the LogEtronic printer prior to performing the profile scanning operation, since the photo-cell would then be picking up photo detail having uniform density and contrast.

Use of a rotating shutter system in lieu of the dichromatic system may also result in improved image resolution. To preclude motor disturbances, the shutter could be attached to the tracing table instead of the operator's headgear. It would be desirable to have a rotating shutter placed in front of the photo-cell and have it synchronized to one of the projector shutters so that imagery is received from only one diapositive.

(3) *Adaptation of the Orthophotoscope* (letter *G* in Figure 3)

Use of the Orthophotoscope to obtain a restituted photo of the projected stereo-image is also worthy of consideration. This device is currently employed in conjunction with an oriented spatial model formed in a projection-type stereo-plotting instrument employing dichromatic projection systems. The scanned images are orthophotographically projected, through a slit, onto a film sensitive to blue light.

Uniform scanning speed is required to obtain uniform exposure throughout the entire model. This is a decided disadvantage of this instrument, for it requires an operator to keep pace with the moving slit, thereby presenting problems of operator fatigue. It appears that use of an iris diaphragm, keyed to the rate and position of scan, placed in front of the emulsion surface, and below the entrance window, would alleviate this condition. The iris diaphragm might also be used to an advantage in either of the photo-cell scanning techniques mentioned above. Introduction of a variable slit width would also be advisable to accommodate the varying types of terrain and cultural features to be encountered. For example, the size of the slit would be large in areas containing low or moderate relief and where planimetric details were sparse. Conversely, the slit size would be small for areas containing dense culture and relief. The number of scans per stereo model would, therefore, be dependent upon terrain and cultural characteristics present.

It should be noted that the number of exposure scans would not necessarily be the same as that required for scribing profiles. For example, provision could be made to have the slit cover a $\frac{1}{4}$-inch scan while the profile was being scribed at 1/16-inch intervals. Exposures would then be taken only at every fourth profile scan.

(4) *Terrain model exposure* (letter *H* in Figure 3)

Consideration has been given to carving a three-dimensional model directly with a stereo-plotter; i.e., going directly from letter *A* in Figure 3 to the system illustrated at letter *K*. The resulting terrain model could be positioned under the spatial model and, if coated with a photo-sensitive emulsion, the aerial image could be developed onto the surface of the terrain model. Orthographic photography of this model would yield restituted imagery.

This approach has been initially evaluated an unsatisfactory because of the need to carve a large block of wax due to the projected scale of the model, the controlled photographic steps involved, excessive instrumentation demanded and the questionable resolution attainable from developing an image on the routed surface of the terrain model. Use of alternately colored layers of wax further detracts from the photogenic qualities of the model.

C. RECORDING AND STORAGE OF PROFILES SCANNED

(1) *Mechanically scribed profiles*

Early in this study, it was apparent that problems of scale encountered in carving terrain models into blocks of laminated wax directly from images of the stereo-model were formidable. This necessitated the search for a method whereby the profiles scanned could be recorded for subsequent use to produce terrain models at conventional publication scales.

Based upon the experience gained in the AMS study "Stereo-Carving Instrument Development" (reference 1), in cutting single sheets of wax by the profile slice method, and the work of Ray (reference 4), it was believed that a superior means would result if the profiles were scribed onto scribe coated materials. The crisp lines resulting from the scribing operation should simplify the tracking of the profiles by an electric eye in subsequent operations relating to producing map and model products at scales smaller than that of the originally projected spatial model. The scribe coated materials also provide for an excellent stable base and library storage medium.

Present Multiplex or Kelsh-type plotters need only to be equipped with a rack and pinion arrangement which permits the setting of the desired "*X*" increments (dependent upon scale used) and a straightedge to guide the operator in the "*Y*" direction. The scribing tool may be attached to the tracing table or driven by a coordinatograph to record the profiles scanned. An arrangement whereby each recorded profile is indexed and numbered would be required in order to permit rapid selection of the number of profiles needed. This requirement is discussed in detail in a subsequent paragraph.

(2) *Tape recording of profiles* (letter *I* in Figure 3)

Tape recording of continuous profiles is theoretically possible. Industry has procedures whereby machine operations are controlled by programmed tape recordings. However, the bits of information required to record continuous profiles is so voluminous that several rolls of tape would be necessary to record the profiles from a single stereo-projected image. There is also no means for the operator to visually check any of the profiles being scanned. These facts, coupled with high costs associated with such equipment, make it impractical to consider this approach at this time. With the evolution occurring in the field of taped programs, however, it may well become economically attractive to the problems at hand.

d. DEVELOPMENT OF THE MASTER TERRAIN MODEL (letters *K* and *J* in Figure 3)

The final AMS report, "Stereo-Carving Instrument Development" (reference 1), covers in considerable detail the initial tests which established the feasibility of cutting a terrain model directly from aerial photography source material, employing a photogrammetric plotting instrument and the profile scanning technique. Since the publication of the referenced report, further analysis has indicated the advisability of tying this operation indirectly to the plotting instrument rather than directly. This appears prudent in order to overcome problems associated with the spatial model scale being larger than that required for producing plastic relief maps and, by making the linkage to the stereo-plotter an indirect one, model construction operations can, quite conceivably, become automatic. This referenced work revealed that the terrain model surface, if developed by 40 profile slices per inch (.025 inch), was sufficiently "smooth" to permit the forming of acceptable plastic relief maps without expending additional manhours to smooth the model surface to the degree presently achieved.

If terrain model production is contemplated, it appears desirable to record profiles scanned over the stereo-model at a scale of 1/25,000, and to use these for producing master terrain models at the smaller scales of 1/50,000 or 1/100,000. The following example discloses the relationships involved. Working with photography flown at 20,000 feet, under a Kelsh plotter, the area covered by a single stereomodel would measure approximately 18 $\times$36 inches and would be projected at a scale of 1/8,000. Therefore, to construct a terrain model at a scale of 1/25,000, employing 40 profile slices per inch, it would only be necessary to scan profiles over the stereo-model at the rate of about $12\frac{1}{2}$ scans per inch (.075 inch). This would yield 40 recorded profiles per inch, each having a horizontal scale of 1/25,000. If a terrain model at a scale of 1/50,000 was required. it would only be necessary to use every other one of the 1/25,000 scale profiles recorded; every fourth one of the 1/25,000 scale recorded profiles if a terrain model was made at a scale of 1/100,000.

The system to be practical must, therefore, allow profiles scanned over the stereomodel to be reduced horizontally to map publication scales, and it must also permit the selection of a fewer number of profiles in order to produce models at scales smaller than the stereo-model. Because of these requirements, it appears best to activate the three-dimensional coordinatograph by an electric eye following a scribed profile image which, by optical projection, is reduced to the horizontal scale of the model required.

Selection of fewer profiles could probably be accomplished by mechanical sorting before they are reduced in scale by projection for electric eye following. To overcome the problem of removing, by rough cuts, excess material before the precise profile is cut into the block of wax laminates, the cutter on the coordinatograph could be indexed to cut $\frac{1}{4}''$ to $\frac{1}{2}''$ higher than required for the finished cut. After the excess material is removed, the profiles would be scanned by the electric eye a second time, at a setting required for the finished cut.

To accommodate varying exaggerations of the vertical scale over the horizontal scale, the specifications for the coordinatograph should permit exaggerations of 2:1, 3:1 and 4:1. At this stage of concept, it appears that the scanning of selected and scale-reduced profiles by the electric eye, with subsequent activation of the coordinatograph, could be automatic in performance; an important reason for not attempting to link the cutting of the master terrain model directly with the stereoplotting instrument.

VI. By-Products Derived from the Suggested System

The four objectives being sought from a single photogrammetric exercise have been theoretically satisfied by the various means described under Section V. What can be said of the by-products that would result from the proposed system? They would include:

a. *Developed or extracted contour information* that could be used as scribe guide material for preparing the contour separation and for preparing open window negatives for layer tinting by Dri-Strip techniques.
b. *Restituted imagery* for use as:
   (1) Compilation material for scribing separation plates for culture, drainage, vegetation, etc.
   (2) Material for photomaps or photomap back-ups to the topographic edition.
c. *Profile library* for use in producing map and model products at smaller scales.
d. *Master terrain models* for use in:
   (1) Producing plastic relief maps or molded photomap reproductions.
   (2) Bench camera photography to yield:
      (a) Shaded relief plates for subsequent overprinting upon the flat map edition.
      (b) Contour information to serve as scribe guide copy for maps at smaller scales.
      (c) Scribe guide images from which open window negatives for layer tinting can be prepared by the Dri-Strip technique.
      (d) Special terrain model views.

VII. Discussion: Benefits Derived from Proposed System

The benefits expected from the system proposed have not, as of this date, been completely verified, but their combined potential is of such magnitude that early disclosure is warranted, even though further study and testing will undoubtedly make obsolete their discussion at this time.

a. INCREASED CAPACITY FOR PROCESSING NEW AERIAL COVERAGE

This appears to be a logical expectation since the profile scanning of the stereomodel, as proposed, preserves the spatial model in convenient form so that compilation can be performed by personnel other than the stereo-instrument operator. This frees the instrument operator to resume the scanning of new coverage.

Some idea of the time that could become available for processing new coverage can be estimated, based upon the rate of scanning currently possible under the Orthophotoscope. Under this instrument, four scans in the "X" direction are made for each inch advanced in the "Y" direction. A stereo-model, as projected by the Balplex plotter, is scanned with the Orthophotoscope in about two hours. For the system proposed in this report, four scans per inch are normally insufficient and the constant rate of scanning (about four seconds per inch) contributes to operator fatigue. For 1/25,000 publication scale, working as proposed under a Kelsh instrument, a minimum of $12\frac{1}{2}$ scans per inch in the "Y" direction is indicated as necessary for areas of dense culture and rugged relief. Since the projected model measures approximately 36×18 inches, for 60 per cent forward-lap photography, 225 scans, 36 inches long, would be required. It is estimated that three minutes should be allowed per 36-inch scan, for a total of 675 minutes or $11\frac{1}{4}$ hours per stereo-model.

The time required to compile a stereo-model, under present practice, is reputed to vary from 10 to over 100 hours, with an average of 40 hours per model. The amount of new coverage that could be processed by the suggested system would be increased, on the average, by a factor of about 3.5. It is suspected, furthermore, that the amount of time saved would be in proportion to the complexity of the culture and relief encountered; i.e., scanning highly cultured areas or areas of high relief should take very little longer than the time spent on "easier" models, yet the total time for stereo-compiling complex models under the present procedures rises sharply per the degree of complexity encountered. This saving becomes more convincing when it is realized that under the system proposed, instrument operators would not be held up waiting to tie their respective works with other compilers working on contiguous areas. The fact that contours developed by dropped lines or dots or routing laminated wax sheets provides visible evidence of the ability of an operator to "keep the dot on the ground" should ease the problems of supervising this phase of the work.

b. SAVINGS IN ELAPSED TIME TO PRODUCE COLOR SEPARATIONS

That savings of time are possible in this area becomes evident when one compares the present operations necessary to produce final scribed color separation negatives, with the work flow that could be expected from the system proposed.

(1) *Present procedure*

Following the absolute orientation of the stereo-model, the stereo-compiler drops the cultural features, contour data, drainage and vegetative details. The compiler then makes appropriate reference to contact prints of his aerial coverage that has been annotated by field parties, and edits the compilation for necessary additions and corrections. The dropped contours are reshaped in pencil. After a supervisory check, inking in monochrome of the complete manuscript follows.

At this point, the work leaves the booth and is sent to the photographic laboratory where the stereo-projection is reduced to the photogrammetric format scale. In large scale compilations, this format scale would approximate 1/25,000. From the resultant positives, a mosaic is laid per the control grid previously prepared. Following this, a careful edit is performed to insure that cultural and topographic features are in concert and tie properly throughout the mosaic. At this point, it is passed to the cartographic draftsman.

In preparing for the scribing of color separations, the photogrammetric mosaic is again sent to a photographic laboratory where a V-base negative is prepared at map publication scale; i.e., 1/25,000 if the photogrammetric manuscript was at a scale of 1/20,000. This V-base negative is inverted to yield a reverse reading positive image by contact exposure which again becomes a negative after the scribing operation.

(2) *Suggested new procedure*

Following the profiling of the stereo-model, the products, in the form of contour extractions and restituted imagery, would be passed to the photographic laboratory where positives would be made at the map publication scale. These, in turn, would be laid as a mosaic per the control grid, one for restituted imagery and one for the extracted contours. These two mosaics, along with the large scale contours, restituted prints and contact prints annotated by field parties, in addition to any other source material, would be passed to the cartographic compiler. The two mosaics would be processed onto orange scribe coated stock as overprinted *right-reading* positive scribe guides. The compiler would make reference to the annotated coverage at his disposal and draw on the scribe guide copy of the restituted imagery any clarifying annotations. He then would proceed to scribe the culture.

Simultaneously, another compiler, working with another scribe guide of the contour information extracted by profiling, would scribe the contour separation.

When the culture and contour separations were complete, they could be put together as scribe guides along with the image of restituted photography so that the drainage separation could be scribed. Other compilers could be preparing urban area and road-fill separations, or preparing vegetation and names overlays. All separations would be right-reading positives and would constitute final copy for the reproduction processes. Reverse positives would be prepared from the separations for the deep-etch plate preparation that would follow.

It seems, from the preceding, that the time in the production stream, when more individuals could be assigned to the compilation, is considerably advanced by the system proposed. This is an effective means of reducing the elapsed time required to complete color separation. Furthermore, the proposed system reduces the number and complexity of skills presently demanded of stereo-compilers. It should prove easier for a map production plant to train individuals to profile stereo-models, and others for the task of compiling the results of the scanning operation, rather than train stereocompilers in all the necessary skills as required under existing procedures.

C. ELAPSED TIME AND ACTUAL TIME SAVED FOR TERRAIN MODEL CONSTRUCTION

The most obvious saving envisioned of the proposed system relates to the drastic elapsed and actual time reductions for constructing master terrain models. These models could be prepared well in advance of color separations, thereby saving hundreds of hours which now must be expended *after* the base map has been compiled. It should be recalled, furthermore, that plastic reproductions formed over a terrain model cut by profile scanning were found to be acceptable, reference 1. This means that the present long and tedious hours spent in smoothing and developing the model surface would no longer be necessary. Also, the construction of terrain models from selected and scale-reduced profiles is envisioned as being an automatic operation. The proposed system would bring to relief mapping a cost reduction urgently needed to increase the availability of plastic relief maps.

VIII. Recapitulation on Disadvantages of Profile Scanning

Some apparent disadvantages to profile scanning were cited under Section III. The proposed system overcomes some, but not all, of the objectionable features mentioned. The proposed profile scanning operation does not provide a means of establishing spot heights; however, this could be performed after the scanning operation was completed, similar to present methods. The proposed system has not lowered instrumental costs, but the potentials appear to be of such magnitude that moderate increases in equipment costs could be easily amortized.

Personnel conducting initial tests on profile scanning have pronounced it to be a straightforward operation. Indoctrination of stereo-instrument operators in profiling their models, therefore, should not be long in duration.

The factor of job boredom, cited previously as a possibility, may well result with the system proposed. However, special attention can be given to developing prototype equipment for scanning, to design details that ease the task required to be performed, such as the proposal to employ a universal steering wheel device similar to that on the Nistri Photostereograph, Model BETA/2. The possible introduction of a rotating shutter system in lieu of the dichromatic projection system, as advanced earlier in this report, may eliminate the annoyance of working with glasses containing red and blue filters.

It should be realized, however, that job boredom is not unique to the system proposed in this report, for it is a factor at play under existing photogrammetric operations. Furthermore, job boredom cannot be the predominant reason for rejecting any improved process; effort, instead, should be placed on finding new ways of combating the problem.

Finally, it is important to view this particular problem in proper perspective. It may take on different proportions in the future, for automatic scanning of the stereo-model, either vertically or horizontally, may become a new capability.

IX. Conclusions and Recommendations

Preliminary study of profile scanning the stereo-model strongly suggests multiple benefits. Through this photogrammetric departure, a *single* plotting (profiling) exercise can record, transform and preserve the stereo-model in convenient form, permitting map compilation to be more rapidly accomplished, terrain models to be expeditiously constructed and an impressive increase in the amount of new photography that can be "processed" by a given photogrammetric facility.

The benefits envisioned from the integrated mapping system presented in this paper are believed to be of such magnitude that continued study leading to the development of requisite equipment is warranted. It is the hope of the authors that disclosure of this integrated system will stimulate further analyses and refinement by others, and, with the cooperation of photogrammetric instrument designers and manufacturers, efficient profiling instrumentation will be forthcoming.

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*Utilization of Photogrammetric Mapping and Electronic Computers for Highway Design**

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THE subject of this paper in my opinion, is of the utmost interest not only to members of the American Society of Photogrammetry but to all Federal, State, local and Consulting Highway Engineers who are dedicated to the purposes of increasing engineering productivity by the utilization of modern scientific methods.

Previous speakers at this meeting have described how photogrammetric maps are used by the New York State Department of Public Works in the initial stages of highway design, namely route selection. I will start from that point and present some of our organization's experiences in using photogrammetric mapping in connection with highway design and construction, as well as some of our initial experiences in using an electronic computer in connection with highway design computations.

About a year and a half ago our organization was retained to render survey and design services for the New York State Dept. of Public Works in connection with a section of the proposed Interstate Route No. 5 in the Watertown Area. In order to meet the requirements of a desired schedule, we studied the feasibility of utilizing photogrammetric mapping for the preparation of the necessary survey maps and bridge site plans, at the scales of 50′ to 1″ and 20′ to 1″ respectively, which are ordinarily used to prepare preliminary design plans as well as contract plans for highway and structures required. Consideration of such a plan required the approval of the State Department of Public Works. We were favored by the fact the photogrammetric mapping at scale of 200′ to 1″ and with 5′ foot contours had been accomplished for the entire section of this proposed highway, for purposes of route selection.

With the encouraging approval and guidance of District Engineer Robert Sweet, under whose supervision our engineering services for this project were performed, we were able to convince the Chief Engineer of the State Department of Public Works at Albany to accept contract plans designed and prepared from photogrammetric mapping at scale of 50′ to 1″ and contoured for vertical control at 2 foot intervals. In order to do this, we agreed to

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