G. L. Hobrough
Itek Corporation
Palo Alto, Calif.

Automation in Photogrammetric Instruments*

It will be interesting to observe over the next decade how the advance in automation will keep pace with the flood of image data from improved acquisition systems.

(*Abstract on next page*)

Introduction

The terms "mechanization" and "automation" are often used synonomously to indicate the replacement of a human operator by a machine. "Automation" as used in this paper implies that some aspect of the operation being performed is sensed and that the information thus obtained is used to control the further progress of the operation. The recent rapid advances in automation have been made practicable by the availability of electronic sensing techniques and the development of a control and servo-mechanism theory; the automation of map making has been similarly influenced.

The incentive is strong to reduce manual participation in all phases of the mapping process and considerable progress has been made in this direction. Mapping can be divided broadly into data-gathering, data-reduction, and data-presentation phases. The gathering phase or field work constituted the bulk of the work in mapping operations until the advent of aerial survey. Aerial survey has mechanized this phase of map making to the point that ground survey now is necessary only for the establishment of control points in the aerial photographs. The requirement for ground control has been simplified further by the development of electronic distance-measuring equipment such as Shoran, the Airborne Profile Recorder, the Geodimeter, and the Tellurometer.

The data-collection phase of map making has been simplified and mechanized to the point that most of the time and a large portion of the cost of a mapping project now relate to the data-reduction and the data-presentation phases. The data-reduction phase is generally called photogrammetry and involves the derivation of terrain dimensions from measurements taken in the photographs. The data-presentation phase, generally called cartography, involves the drafting of the terrain features to be incorporated in the final map and their assembly and printing.

This paper outlines the history of automation of photogrammetry and will attempt to set forth the nature of the basic problems. Recent developments in the automation of cartography are also dealt with briefly.

Stereo Plotting Instruments

Mapping photogrammetry can be subdivided into compilation and aerial triangulation. In compilation topographic and planimetric detail is plotted from pairs of stereo photographs on a stereo plotting instrument. In aerial triangulation the numerous aerial photographs involved in a survey operation are related to each other in order to reduce the need for ground control to a minimum. In both compilation and triangulation the locating of corresponding or homologous points in stereo images, that is, the detection of parallax, is the primary sensing operation. This operation has been successfully automated only recently. Compilation also involves the detection, recognition, and identification of specific image details, but to date little significant progress has been achieved in the automation of these functions.

The development of the digital computer provided electronic methods that could

* Published in 1964 by the International Training Center for Aerial Survey in the Jubilee Volume dedicated to Willem Schermerhorn.

achieve, for the first time, the precision necessary for the handling of photogrammetric data. Digital computer techniques have been applied to many photogrammetric problems and are used extensively to simplify the handling of the large amount of numerical data associated with aerial triangulation. With respect to photogrammetric instrumentation, digital readout devices are currently used to print out numerical data from stereo comparators and plotters, and servo-operated coordinatographs are used to plot data from plotters in graphical form.

Stereo plotting is generally considered to be the most tedious and time-consuming photogrammetric task. During plotting all image points to be considered in the compilation of a stereo model must be viewed in a stereoscopic manner by the operator and many of these points must be brought into accurate register with a reference point, thereby to determine coordinates in three dimensions. The compilation of a complete model from a single pair of aerial photographs requires many hours of work by a skilled operator on an expensive stereo-plotting instrument.

Stereo-plotting instruments are complex optical viewers which allow the operator to observe pairs of aerial photographs as stereograms in which the terrain surface is presented in clear and, in fact, exaggerated relief. A reference or "floating" mark is generally provided and the operator can place this mark at any point on the terrain surface.

The design of plotting instruments is complicated by two functional requirements that are to some extent in conflict. The first requirement is to provide the optical arrangement which allows the operator to view the plates stereoscopically. Since the operator will be viewing the images over extended periods of time, considerable attention must be given to image quality and to factors contributing to visual fatigue. In particular, the instrument must provide sufficient magnification to allow the operator to observe easily the finest detail resolvable in the photographs. The second requirement of the plotting instrument is to furnish a means for accurately relating image points on the photographs to model points in three dimensions (restitution).

Optical and mechanical analog arrangements have been employed for restitution in the past, but unfortunately such arrangements generally complicate the viewing of the plates and lead to a reduction of image quality and to a narrowing of the visual field. Nevertheless, stereo plotting instruments have been developed to a remarkable level of performance and the quality and accuracy of the instruments is generally in excess of the resolution and stability of the photographs used therein.

ABSTRACT: *Since 1950, automation in photogrammetric operations associated with map making has been achieved principally through the development of electronic methods, but certain non-electronic approaches appear to offer distinct advantages. The continued development of automatic photogrammetry, whether by electronic or other means, will require improved solutions to the two basic problems of sensing of image parallax and corrective transformation of stereo images to higher orders.*

AN ANALYTICAL plotter in which an electronic digital computer replaces the optical or mechanical analog elements of a traditional plotter has recently been introduced and is described elsewhere in this volume. Such a plotter should be capable of the increased accuracy and flexibility associated with digital computation. In addition, an analytical plotter permits a greatly simplified optical-mechanical system that can be optimized more easily for operator convenience and comfort.

The design of stereo plotting instruments has been a challenge to the optical instrument industry, and the industry has responded with a variety of designs representing different approaches to the basic problem and reflecting regional preferences and attitudes. Regardless of the details of plotter construction, however, stereo plotting remains a tedious and time-consuming operation requiring a relatively large number of operators with better-than-average depth perception and with considerable experience and training. As a result, many attempts have been made to reduce the complexity of the stereo-plotting operation and to automate all or part of it.

The development of the orthophotoscope is an example of the mechanization of stereo plotting.[1] Orthophotographs may be used as a direct substitute for drawn planimetry in many applications. Where drawn planimetry is essential it may be produced from orthophotographs on a light table, thereby releasing the stereo-plotting instrument and its operator for other purposes. The production of orthophotographs by means of the orthophotoscope is considerably more rapid than the drawing of planimetry but unfortunately it also is a tedious operation requiring an operator with good depth perception. The automation of orthophoto printing is therefore of considerable interest along with the automation of contour or profile tracing.

The automation of all stereo plotting requires a means for the rapid and accurate sensing of parallax between stereo images. This paper will deal principally with the discrimination and clearance of parallax by electronic means. In spite of certain difficulties associated with the application of electronics to image manipulation, electronic methods, with their great speed, flexibility, and familiarity, appear to be the first choice for the automation of photogrammetry at the present time. The application of several recent non-electronic methods will also be discussed briefly.

Electronics and the Necessity for Scanning

Automation as defined here implies the sensing of some aspect of an operation being performed. Unfortunately, the sensing of image parallax is difficult and the difficulty arises out of the fact that photographs and optical images are simultaneous presentations of image element data; whereas electronics presents data sequentially one element at a time, that is, electronic data is single valued with respect to time.

A two-dimensional image such as a photograph is converted into a single-valued time function suitable for electronic processing by scanning the image. Scanning in this sense means an examination of an image, element by element in succession, along a line defined by a moving spot, and the generation of an electrical "video" signal whose magnitude is proportional to image density at each point. Since the image to be examined is two-dimensional, numerous scanning lines are required to convert all of the information on the image into sequential signal values.

Scanning lines may be combined in a number of ways to cover an image area. The pattern chosen for a particular application is usually one which simplifies the subsequent utilization of the information extracted. Regardless of the scanning pattern employed, some of the spatial relationships between the various parts of an image are scrambled in the process of scanning. However, by careful synchronization of the scanning operations at, say, a television camera and receiver, the spatial relationships of an electronically transmitted image may be re-established again at the receiver. Unfortunately, during the transmission of the image information through the circuits, the spatial relationships are not evident, and electronic equipment is not able, in general, either to sense changes in image relationships or to make decisions based upon them. It is this basic incompatibility of dimensions that has delayed the application of electronic methods to the automation of parallax clearance and other image manipulations.

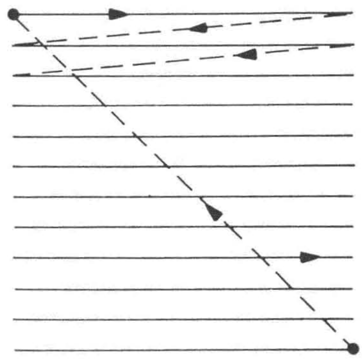

Fig. 1. TV scanning raster.

Scanning Patterns

We will consider briefly three quite different scanning patterns as they relate to parallax sensing.

The most familiar scanning pattern is the conventional TV "raster" illustrated in Figure 1. With this pattern the image area is covered by horizontal lines spaced uniformly in the vertical direction. The spot commences scanning at, say, the upper left corner of the picture area and then moves at a constant velocity to the right forming a scanning line across the top edge of the picture. Upon reaching the upper right corner of the picture, the spot disappears and reappears again at the left side of the picture at a point immediately below the starting point. The second line is then scanned from left to right immediately below the first, the spot disap-

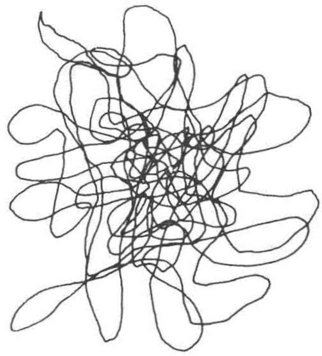

FIG. 2. Random scanning pattern.

pearing at the right side as before and reappearing on the left to produce a succession of adjacent horizontal lines. The dotted retrace lines in Figure 1 have been added to show the sequence of motions followed by the spot, which is in fact extinguished during the retrace periods.

Distance in a scanned image is represented by time in its video signal; that is, the time interval separating any two elements in the signal is proportional to the distance separating the corresponding image points along the scanning line. Obviously, the analog between time and distance is effective only in the direction of scan and any two points in the image area which do not happen to lie on the same scanning line cannot have their separation indicated by a time measurement in a simple manner.

PARALLAX DETECTION

By scanning stereo images simultaneously and in synchronism, parallax may be detected in the direction of scan through differences in the times of arrival of left and right video signals. If TV rasters are used and if the lines of the rasters are both arranged to be exactly parallel to the X-axis or base line, then such time differences are a sensitive indication of X-parallax.

A TV raster extracts image information in a form which simplifies the transmission and reconstruction of an image as in television. However, for image registration purposes the TV raster suffers from the disadvantage that parallax can be detected only in a horizontal direction. The TV pattern is therefore unsuited to the comparison of electronically reproduced images for registration in two dimensions, wherein both horizontal and vertical parallaxes must be sensed simultaneously. There are a number of patterns more applicable to comparisons of this type. In general, such patterns scan each image point in several directions to provide a displacement-time relationship in two dimensions.

The random pattern shown in Figure 2 has been used for the detection of parallax.[5] A random pattern may be produced by moving the scanning spot in response to two separate random noise signals. One such signal may move the spot in, say, the X-direction in which case the other signal would move the spot in the Y-direction. A random pattern is isotropic in the sense that there are no preferred directions of scan and is therefore suitable for comparing images for parallax or registration. Unfortunately, owing to its irregular nature, the random pattern is not suitable for the reproduction of images.

A scanning pattern made up of crossed diagonal lines is illustrated in Figure 3. The uniform density of scanning lines and the constant velocity of the scanning spot combine to provide a uniform pattern suitable for the electronic reproduction of images. The motion of the scanning spot in two mutually perpendicular directions permits the detection of parallax to be made directly from time difference measurements also in two perpendicular directions.

Parallax detection is essentially an electronic correlation operation and requires that the video signals be closely similar except for moderate time differences representing parallax. The images from stereo photographs of rough terrain may differ considerably in local scale and orientation and the history of automation has been governed in part by the evolution of means to accommodate these differences.

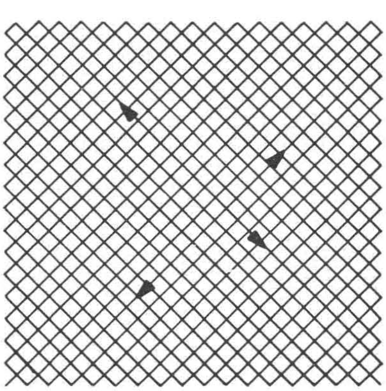

FIG. 2. Crossed diagonal scanning pattern.

Evolution of Automation

Development of automatic plotting instruments has evolved more or less through the following four stages.

First efforts were experimental in nature and were directed to the detection of parallax in the *X*-direction using a TV scanning raster and elementary electronic correlation circuits. Correlation of simple, bold image patterns was achieved in some cases. Much of this early work was performed under sponsorship of the U. S. Army Corps of Engineers commencing in 1950.[3]

The second stage saw development of instruments employing more sophisticated electronic circuits wherein stereo photographs of relatively smooth terrain could be correlated and parallax could be detected. One of these instruments (Stereomat II) employed a random scanning pattern and was able to detect and to clear *X*- and *Y*-parallaxes simultaneously. Automatic profiling and contouring were achieved with these machines and the feasibility of automation was demonstrated. Unfortunately, however, these instruments did not perform well in areas of severe terrain slope and roughness owing to loss of correlation.

The third stage saw the application of linear transformations to the scanning patterns to improve correlation. A machine employing linear transformation operates in the following manner: Average parallax over the entire image area is detected in an approximate way to give corresponding *X*- and *Y*-parallax error signals. The scanning patterns are then displaced with respect to the stereo images in response to the error signals until the average parallax is reduced essentially to zero. Under these conditions the scanning pattern as seen stereoscopically in model space appears as a horizontal plane intersecting the terrain surface. A linear transformation machine employs circuits to detect local parallaxes within the pattern area and to evaluate the direction of terrain slope from this information. Transformation of the scanning patterns is then automatically applied in response to the local parallax signals and in a direction to reduce local parallaxes to a minimum value. Under these conditions the scanning pattern as seen in model space is a plane tangent to the terrain surface.

The transformation of scanning patterns to conform to terrain slope reduces differences between the left and right video signals, thereby improving the action of correlation and parallax sensing circuits. Several machines employing this principle have been developed and have proven to be capable of automatic profiling and contouring over a wide range of terrain conditions.

The fourth and present stage in this sequence involves the provision of second-order transformations to the scanning patterns to accommodate simple terrain curvature. A second-order transformation capability also accommodates photography exposed in oblique cameras and in cameras that do not conform to conventional perspective geometry. Third and higher order transformations are also possible but the number of degrees of freedom increases rapidly with order and each degree of freedom requires separate transformation and detection circuitry. A second-order system involves 12 degrees of freedom; a third-order system would require 20. Also, higher order transformations contribute progressively less improvement to correlation.

Figure 4 is a chart showing the history of automation in the United States and Canada from 1950 to the present. Automatic plotters reported to date profile and contour about 3 to 10 times faster than a human operator while meeting map accuracy standards.[8,13] Speed, accuracy, and repeatability of orientation are reported to be better than manual operation by a factor of 2 to 5. As with manual operation, accuracy appears to be governed fundamentally by film resolution and dimensional stability, and by instrument and camera calibration. Also, contrary to popular belief, the failure rate of these electronic instruments is remarkably low.

Several automatic plotters are able to print orthophotographs automatically.[4,11,12,14] In each of these devices a photo-map is printed from a cathode ray tube projector which images a small portion of one of the stereo photographs onto a sheet of light-sensitive film. As the projector moves over the sensitive sheet, the scale and position of the imagery is adjusted in response to height information derived from the electronic correlation of both stereo photographs. The action is automatic and a complete stereo overlap can be printed in from 2 to 4 hours at present.

Most automation efforts have been directed toward rapid electronic or mechanical scanning of stereo image areas, electronic circuitry of one kind or another being used to determine match or mismatch immediately. One exception to this approach is a program wherein entire photographs are digitized in *X*, *Y*, and gray scale and a computer per-

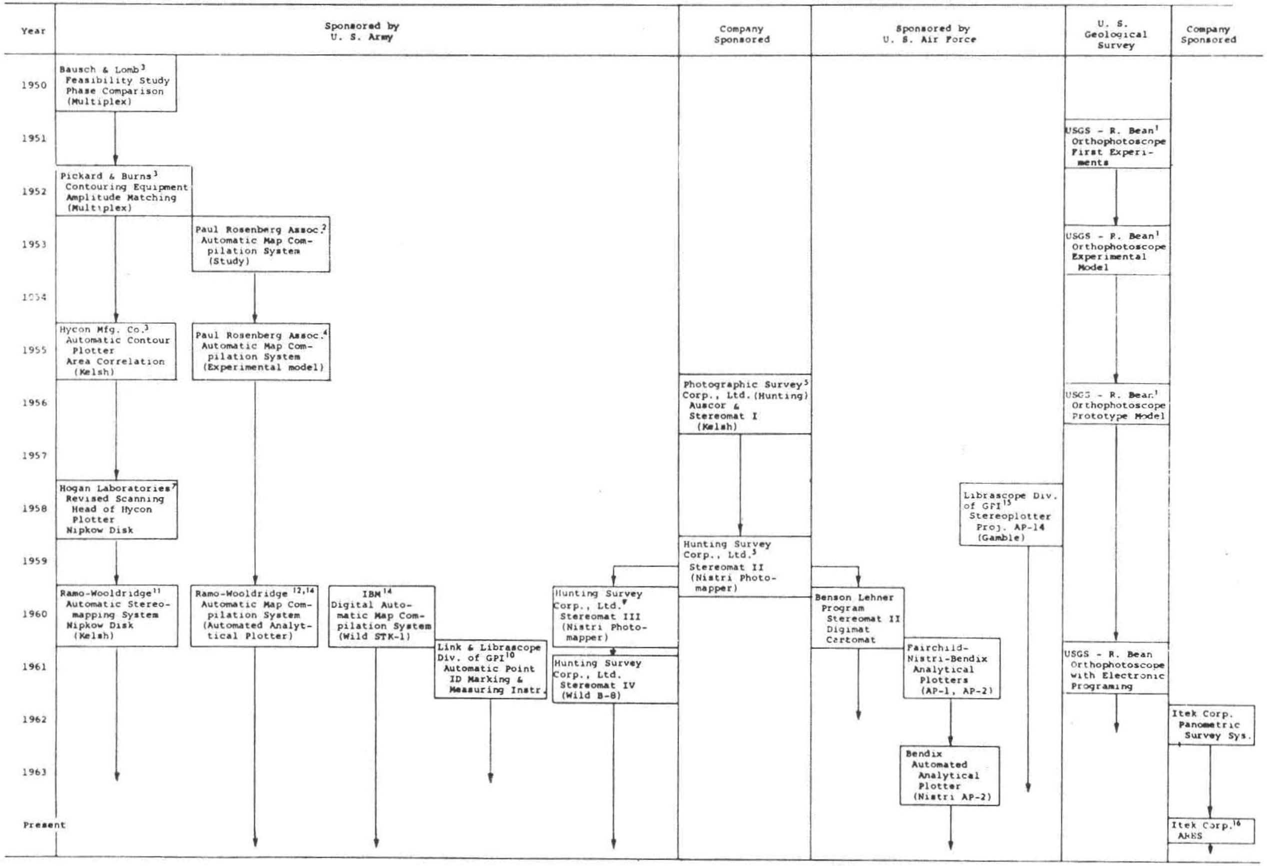

FIG. 4. Automation of photogrammetric instruments.

TABLE 1

Instrument	*Company*	*Sponsor*
Stereomat IV	Hunting Survey Corp., Toronto, Canada	U. S. Army Map Service
Automatic Map Compilation System	Bunker-Ramo Wooldridge, Canoga Park, Calif.	GIMRADA
Automatic Registration Electronic Stereoscope (ARES)	Itek Corp., Palo Alto, Calif.	Itek Corp.

forms the match determination subsequently.[4,14]

As of this date the three automation efforts shown in Table 1 are known to the author and are reported to be meeting with significant success.

The Automatic Map Compilation System has been reported in detail in PHOTOGRAMMETRIC ENGINEERING; Stereomat IV and ARES were reported at the 1964 International Congress of Photogrammetry.[16] The first two instruments are designed to draw contours or profiles and also to print orthophotography; ARES is an automatically fusing stereoscope for convergent and panoramic photography.

FUTURE DEVELOPMENTS

EARLY AUTOMATION programs were built around conventional instruments wherever possible in an attempt to reduce costs. In general, however, conventional photogrammetric equipment is not amenable to automation; heavy moving parts, deflectable structures, and backlash in lead screws all seriously degrade speed and accuracy of the servomechanisms producing the plotting motions. Recognition of this problem is evident in that newer developments are relying upon specially designed optical-mechanical equipment or upon existing instruments that have been very extensively modified.

Within the next three to five years many of the present automation programs should be completed and several of the conventional photogrammetric operations will probably be automated on a more-or-less routine basis. Particularly interesting should be the automation of analytical plotters capable of printing orthophotographs, contours, and digital data. During this same period, instrumentation will probably become available for the correlative transfer of points for analytical aerial triangulation. This equipment will, in all likelihood, rely upon the use of record photographs produced for each pass point and control point. A single photographic record will then serve to identify a point on all of the photographs in which that point appears. The instrument will view the record photograph, move the original photograph until there is a coincidence and then read out the film coordinates of the point in question. The time saved by such instrumentation in an analytical aerial triangulation program should be remarkable, and the decrease in misidentifications and other blunders significant.

Electronic registration also makes feasible less conventional operations. It appears likely, for example, that equipment will become available in which high resolution panoramic photography is combined with lower resolution cartographic photography. The high resolution panoramic photography will be transformed electronically and superimposed upon the lower resolution cartographic photography to serve as interpolative image data. This procedure should enable considerably higher angular resolutions than are available in wide-angle cartographic photographs and consequently allow higher flying altitudes and increased economy.

We have been discussing automation in terms of electronic methods and apparatus. It is interesting to note, however, that many of the functions performed in an electronic system have recently been duplicated by optical or photographic means. In particular, the essential correlative operations of multiplication and filtering may be performed with the advantage that these operations are accomplished in two dimensions, thereby avoiding the dimensional incompatibility of electronics. Generally, multiplication is performed by a photographic process employing high contrast materials, whilst filtering and integrating operations are accomplished optically.

The chief and currently prohibitive difficulty in the application of two-dimensional methods is that of bringing the two images to be correlated into accurate register with each other so that only relief parallaxes remain between them. No doubt this difficulty will be overcome eventually; perhaps electronic image-registration may be employed in an otherwise non-electronic system. It seems reasonable to expect that once the problem of registration is solved contours and profiles may be printed automatically and extremely rapidly by these means.

The sensing of image parallax, by electronic or by other means, enables the automation of many photogrammetric operations, some of which we have described. As mentioned earlier, there has been little progress in the automation of planimetric drafting, chiefly because the sensing of significant image detail or recognition of patterns has not been accomplished.

A human operator recognizes image details principally from the two-dimensional characteristics of the image patterns. Height information is also available in stereo plotting but appears to be used only to resolve ambiguities. Since the recognition of image detail is predominantly a two-dimensional operation, the application of photographic and optical correlation methods would seem to be appropriate to the automation of planimetric drafting. In fact, photographic correlation techniques have been applied recently to the problem and some success has been achieved in identifying and symbolizing simple geometric shapes.[13]

Electronic methods, in spite of their dimensional disadvantage, will probably find application in pattern recognition, particularly when automatic electronic plotting instruments are used for topographic plotting. During topographic plotting an electronic instrument could make available a variety of electrical signals representing different aspects of the imagery and of the terrain surface. For example, the spatial frequency spectra of the images could be evaluated from the video signals directly. Such spectra would be incomplete in that they would represent only those components of the image normal to the direction of scanning; nevertheless, the data may be significant in the recognition process.

The sorting out of image characteristics after they are sensed and their correlation would seem to be operations for an electronic computer. The development of suitable computer programs will probably go hand-in-hand with the development of sensing means. Assuming that progress can be made in the automatic recognition of specific terrain features, it seems reasonable to assume that the application of suitable symbols to separation masters will be a relatively simple matter to automate.

Summary

THE AUTOMATION of photogrammetry has been reviewed from its origins in 1950 to the present. The sensing of stereo parallax has been dealt with in some detail, and recent work in pattern recognition has been mentioned briefly. Scanning and electronic methods have been delineated and the emergence of non-electronic two-dimensional techniques has been discussed.

As one "bottleneck" in the mapping process is eliminated by automation, the incentive to attack other areas is perforce increased. It will be interesting to follow the advance of automation in photogrammetry and cartography over the next decade and to observe whether or not this advance can keep pace with the flood of image data expected from high altitude and satellite photographic acquisition systems.

References

1. Bean, Russell K., 1955, "Development of the Orthophotoscope," PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 4 (September), pp. 529–535.
2. Rosenberg, Paul, 1955, "Information Theory and Electronic Photogrammetry," PHOTOGRAMMETRIC ENGINEERING, Vol. XXI, No. 4 (September), pp. 543–555.
3. Esten, R. D., 1957, "Automatic Contouring," PHOTOGRAMMETRIC ENGINEERING, Vol. XXIII, No. 1 (March), pp. 49–53.
4. Williams, R. E., 1959, "The Automatic Map Compilation System," PHOTOGRAMMETRIC ENGINEERING, Vol. XXV, No. 1 (March), pp. 103–110.
5. Hobrough, G. L., 1959, "Automatic Stereo Plotting," PHOTOGRAMMETRIC ENGINEERING, Vol. XXV, No. 5 (December), pp. 763–769.
6. Cude, W. C., 1960, "Automatic and Semi-Automatic Mapping," PHOTOGRAMMETRIC ENGINEERING, Vol. XXVI, No. 2 (April), pp. 303–306.
7. DeMeter, E. R., 1960, "Optical to Electrical Scanning Transducer for Automatic Stereo-mapping Instruments," PHOTOGRAMMETRIC ENGINEERING, Vol. XXVI, No. 4 (September), pp. 604–609.
8. Blachut, T. J., and Helava, U. V., 1960, "Automatic Stereo Plotting in Small and Large Scale Mapping," Report to the 9th International Congress of Photogrammetry, London.
9. Hobrough, G. L., 1960, "Automatic Stereo," Report to the 9th International Congress of Photogrammetry, London.
10. DeMeter, E. R., 1962, "Automatic Point Identification Marking and Measuring Instru-

ment," PHOTOGRAMMETRIC ENGINEERING, Vol. XXVIII, No. 1 (March), pp. 82–87.
11. Bertram, S., 1963, "Automatic Map Compilation," PHOTOGRAMMETRIC EMGINEERING, Vol. XXIX, No. 1 (January), pp. 184–188.
12. Bertram, S., 1963, "The Automatic Map Compilation System," PHOTOGRAMMETRIC ENGINEERING, Vol. XXIX, No. 4 (July), pp. 675–679.
13. Hawkins, J. K., and Munsey, C. J., 1963, "Automatic Photo Reading," PHOTOGRAMMETRIC ENGINEERING, Vol. XXIX, No. 4 (July), pp. 632–640.
14. DeMeter, E. R., 1963, "Latest Advances in Automatic Mapping," PHOTOGRAMMETRIC ENGINEERING, Vol. XXIX, No. 6 (November), pp. 1027–1036.
15. Birnbaum, M. M., and Salomon, P. M., 1964, "A High-Speed Inertia-Free Automatic Stereoplotting Instrument," Report to the Annual Society of Photogrammetry Convention, Washington, D. C. (March).
16. Hobrough, G. L., and Wood, G. A., 1964, "Automatic Image Registration," Report to the International Congress of Photogrammetry, Lisbon, Portugal (September).

ACTIVITIES OF SUSTAINING MEMBER

KEUFFEL & ESSER COMPANY*

New product development continues to be the major concern of the K&E Photogrammetric Systems Division. The past year has seen several important additions to the PSD line.

Among the most recent new products is the CE-101 Stereoplotting System, introduced at the 1965 ACSM-ASP Congress. This is a modular system, permitting expansion of a low-cost basic plotter into the most sophisticated projection-type anaglyph plotter on the market.

A recent product of the K&E-EAI (Electronic Associates, Inc.) co-operative development program was the introduction this year of the new Magnetic Tape 3500 DATAPLOTTER. This new machine and K&E's field-tested package of basic subroutines for most digital computers have firmly established K&E in the digital plotting field.

Also being marketed by K&E for the first time in 1965 is a small scale digital computer—the PDS 1020. This is a portable, desk-mounted computer primarily for engineering and scientific computations. Its inclusion in the line is a natural extension of K&E competence in engineering computing, originating with such basic engineering tools as the Log Log Decitrig and Decilon Slide Rules.

* Inasmuch as this item was not received in time to appear in the May YEARBOOK issue, the previous year's description was repeated in that issue.

Delivery of the first HE-12 Horizontal Projector to the Photogrammetry Division of the Florida State Road Department was an important event in 1964. The HE-12 permits direct, one-step enlargement and rectification of low altitude photography to very large scale ($1'' = 20'$) for use as the plan portion of plan and profile highway drawings.

1964 saw the introduction of ECARS® (Electronic Coordinatograph and Recording System) II, an electronic device which translates graphic source material into computer-sensible language. This machine will output coordinates and related data on magnetic tape at speeds up to 20 points per second. Like its forerunner, ECARS I, this device features continuous variability, scaling and parallaxing capability. ECARS II offers an option which increases the size of the working area from 30×30 inches to 45×45 inches.

In 1964, K&E purchased the Kargl Instruments Company of San Antonio. The acquisition of this facility is designed to achieve optimum coordination between the manufacturing and marketing operations of the PSD product line.

As part of its "complete line" concept, K&E offers instruments and accessories for the surveyor and mapper; drafting materials, instrumentation and optics for the engineer. The expanding role of product development within PSD reflects how the "complete line" concept is being implemented in this three year old operation.