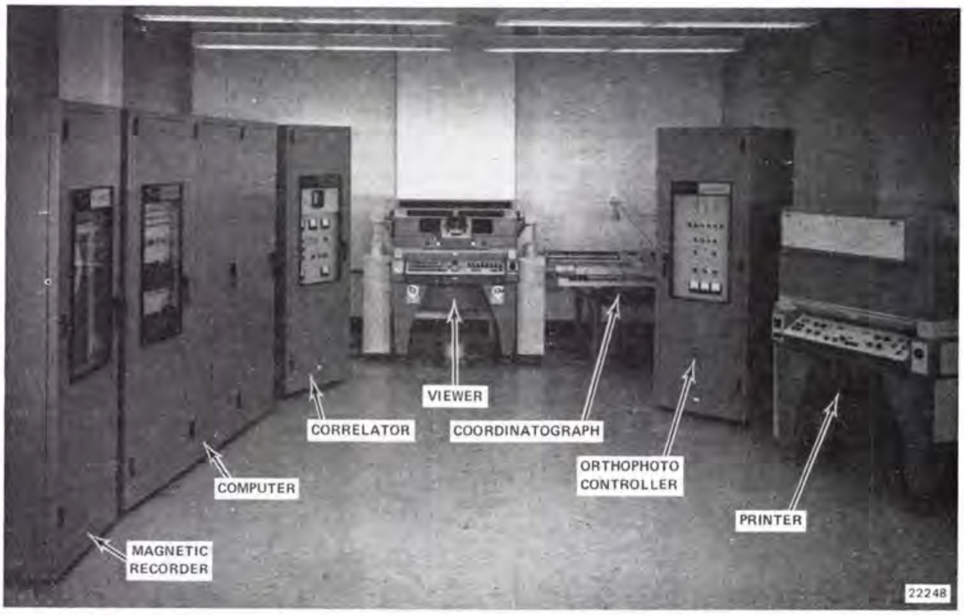


FRONTISPIECE. The AS-11C Equipment.

W. E. CHAPELLE and J. J. EDMOND*
*Bendix Research Laboratories*
*Southfield, Michigan 48075*

# The AS-IIC Automatic System

**This analytical stereoplotter and orthophoto device automatically compile contour graphics, profile graphics, or orthophotos and contours on film.**

(*Abstract on next page*)

## INTRODUCTION AND SUMMARY

THE ANALYTICAL STEREOPLOTTER concept, in which an electronic computer is used in a closed-loop system with observation and measuring devices, has led to highly flexible and accurate mapping instruments. By implementing a mathematical simulation of the input photography, the computer eliminates the restraints associated with physical simulation and thus enables the instrument to handle a wide variety of input materials. The computer likewise permits systematic correction of all known distortions in these input materials. This capability was demonstrated with the AP-2 analytical stereoplotter, and production models, designated AS-11A, are now being extensively used in precision mapping operations.

These instruments employ a relatively simple, but highly accurate, viewing instrument controlled by a stored-program digital computer. The AS-11A provides precision

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manually controlled plotting from frame and panoramic input materials over a wide range of focal length and orientation angles. The computer is programmed to realize the maximum accuracy inherent in the input materials by providing corrections for earth curvature, atmospheric refraction, lens distortion, and film shrinkage. A model-deformation correction is also available to minimize residual errors of unknown origin.

The AS-11A computer programs also control on-line orientation procedures which provide optimum solutions for relative and absolute orientation on a least-squares basis. These procedures rely on the operator only for detection of parallax and recognition of ground control points.

ABSTRACT: *The AS-11C is a highly flexible automatic stereomapping system. It has been developed through integration of electronic image correlation, transformation, and printing equipment with the manually operated AS-11A analytical stereoplotter. The AS-11C retains the capability of the AS-11A to accommodate frame and panoramic input photography with a wide range of focal lengths and orientation parameters. The image correlation system, controlled by the computer, provides automatic contouring or profiling with graphical output. It also provides operator assistance during on-line orientation procedures. The image-transfer system provides latent-image orthophoto printing as the stereo model is automatically profiled. A unique contour output, called the hypsocline, is simultaneously generated and printed on a separate stage.*

The AS-11C system, described in this paper, has been developed to enhance the output capabilities of the basic AS-11A instrument by the addition of an image-correlation system and an electronic orthophoto printer. The AS-11C system provides:

- Automatic contouring with graphical output;
- Automatic profiling in an arbitrarily selected direction, with graphical output;
- Operator assistance during orientation by automatic parallax and elevation measurement;
- Automatic compilation of orthophotographs in latent-image form;
- Automatic compilation of special contour outputs called hypsocline charts in latent-image form during orthophoto compilation;
- Magnetic-tape recording of terrain-surface coordinates during contouring, profiling, and orthophoto compilation.

In automatic contouring and profiling operations, the accuracy of the AS-11C is consistent with that of the manually operated AS-11A. Mean elevation errors of 0.015 to 0.030 millimeter are typical for contours and profiles automatically plotted from materials having scale factors of 1:40,000 or smaller. Plotting is performed at speeds up to 10 mm per second, with the speed being automatically reduced to maintain accuracy in areas of difficult photographic or terrain conditions.

The orthophotographs and hypsocline contours are compiled as the stereo model is automatically scanned in the profiling mode. The compilation scale factor is continuously variable from 0.2 to 5.0, and the choice of profile step-over interval is continuously variable from 0.5 to 5.0 mm. The limiting resolution of the image-transfer system is 60 line-pairs per mm at a compilation scale factor of unity. The hypsocline contour chart, which depicts both terrain elevation and local terrain slope, is printed on a separate stage in the printing unit.

## System Organization

Figure 1 is a block diagram of the AS-11C system, and the Frontispiece shows the equipment. The computer and the viewer, which are the primary components of the AS-11A instrument, retain their basis function of realizing the oriented stereo model throughout all modes of AS-11C system operation.

During automatic contouring and profiling operations, the image-correlation equipment—consisting of the scan generator, flying-spot scanners, and video correlator—provides automatic sensing of model elevation and terrain slope. The correlator outputs are used by the computer to generate the model-coordinate motions for contouring or profiling. The conventional contour and profile outputs are plotted on the coordinatograph with arbitrary scaling.

The orthophotoscope equipment—consisting of the printer and print control logic, video processor, and contour generator—compiles the orthophoto and hypsocline outputs on photographic film. The flying-spot scanners supply the basic image-detail information for the orthophoto compilation. The

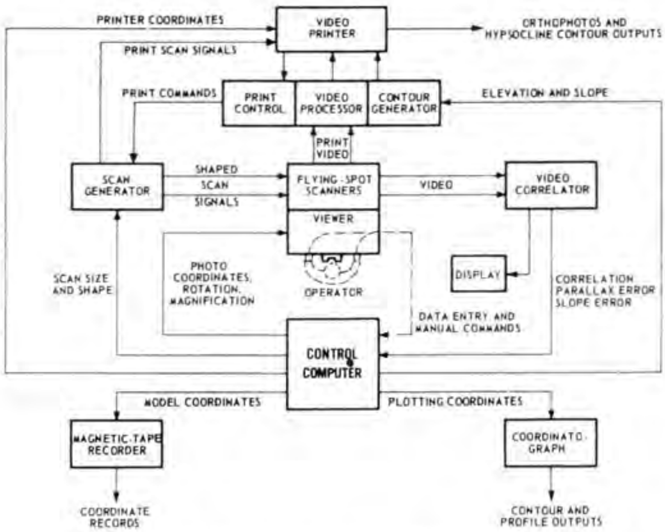


FIG. 1. The AS-11C Functional Organization.

hypsocline chart is derived from computer measurements of elevation and terrain slope.

The AS-11C system also provides magnetic-tape recording of model coordinates during compilation of either the coordinatograph or latent-image outputs. Additional data, selected through the computer, may also be recorded. Recording is performed at selected intervals along the contour or profile line at speeds up to 25 points per second.

VIEWER AND COMPUTER CHARACTERISTICS

The AS-11A viewer is a precision stereocomparator wherein each photograph is servo-controlled by the computer to maintain the correct photo point aligned with the viewing and scanning axis. This operation is accurate to within five microns. The viewer contains high-resolution binocular viewing optics with variable image rotation and magnification for each eyepiece. The optics are controlled by the computer to maintain stereo viewing throughout a convergent or panoramic model. The viewing unit also contains operator controls for data entry and display and for performing manual operations. These include $X$- and $Y$-handwheels, an elevation-control footwheel, and control switches which select computer-stored quantities for display and/or modification.

The photo-position computations are performed by the AS-11A computer at a rate of 100 solutions per second. These computations and other real-time functions are performed by a portion of the computer referred to as the incremental section. This computer section is basically a digital differential analyzer, but it provides a number of special features to accommodate the particular accuracy and speed requirements of the analytical stereoplotter. Associated with the incremental section are high-speed interfaces which accept commands from the operator's handwheels and footwheel and provide output signals to control the viewer servos.

The computer also contains a whole-number section, which has the same basic structure and capabilities as those of a general-purpose computer. In the AS-11A system, the whole-number section is used for such purposes as:

★ Reading and punching tapes,
★ Decimal-to-binary and binary-to-decimal conversions,
★ Interrogation and interpretation of viewer control-switch positions,
★ Calculation of orientation elements for relative and absolute orientation.

In the AS-11C system operation, the functions of the computer are expanded to include all computation and control operations required for automatic plotting. The additional real-time functions performed by the incremental section include:

▲ Clearing elevation error and $Y$-parallax,
▲ Controlling scan shape to compensate for the effects of camera orientation, camera geometry, and terrain slope,
▲ Controlling scan size to minimize elevation-measurement error,
▲ Generating plotting motions for contouring and profiling,

▲ Controlling plotting speed to limit the dynamic error,
▲ Generating scaled model-coordinate signals which drive the coordinatograph, printer, and hypsocline contour generator.

The additional functions performed by the whole-number section include:

♦ Detecting plotting boundaries or contour closure and controlling indexing to the next plotting line,
♦ Controlling automatic searching procedures when loss of correlation occurs,
♦ Recording coordinates of plotting gaps for subsequent manual fill-in,
♦ Selecting the preferred video signal for orthophoto compilation.

The input-output interfaces associated with the incremental section are also expanded in the AS-11C system to provide real-time communication with the image correlation and orthophoto equipment.

IMAGE CORRELATION EQUIPMENT

Referring to the Frontispiece, the electronic portions of the image correlation equipment, including the scan generator, the video correlator, and their associated computer interfaces, are housed in the correlator cabinet. The flying-spot scanners are integrated with the AS-11A viewing unit. The two flying-spot scanners employ separate CRT's (cathode-ray tubes) to scan conjugate areas of each photograph. For each CRT, the scan generator produces scan patterns that are controlled in size and shape by information from the computer. A model-coordinate scanning pattern is first generated by two triangular waves of differing frequencies. The scan-shaping process then transforms the scan pattern for each photograph into the photo-coordinate system and compensates the pattern for the local terrain slope.

The scan pattern generated on the face of each CRT is optically transferred to the photocarriage, duplexed with the viewing illumination, and imaged on the photograph. The transmitted CRT illumination is separated from the viewing illumination and detected by a PMT (photomultiplier tube) whose video signal output represents the image detail intercepted by the scanning spot.

Color-separation techniques are employed in the flying spot-scanners to retain utilization of the manual viewing optics throughout all modes of automatic operation. High-efficiency duplexing and separation of the scanner and visual illumination is obtained by use of dichroic mirrors which reflect the violet (3800 Å) scanner illumination and transmit the yellow-green (5000 to 6000 Å) viewing illumination.

The video signal outputs of the flying-spot scanners are processed by the video-correlator circuitry to obtain five signals which are transferred to the computer. These signals are:

$P_X$, the $X$-parallax error,
$P_Y$, the $Y$-parallax error,
$\epsilon S_X$, the $X$-terrain slope error,
$\epsilon S_Y$, the $Y$-terrain slope error,
$C$, the cross-correlation signal.

The computer uses the correlator output signals to control the automatic terrain-sensing plotting processes. The following paragraphs describe the characteristics of these signals and their use in statically sensing the terrain surface. The next section describes the generation of the plotting motions.

The cross-correlation signal output of the video correlator represents the quality of image registration. A high value of cross-correlation generally occurs when the parallax and terrain slope errors have been eliminated in an area containing substantial image detail. The signal approaches zero as the images are significantly displaced as, shown in Figure 2, or in areas containing very little correlatable information. In static operation, the cross-correlation signal is used to control the size of the scanning pattern. In areas of good correlation, the scan size is reduced to maximize the accuracy of elevation measurement. In areas of poorer correlation, the size is increased to avoid losing correlation. The model-coordinate scan pattern covers a square area which is variable in size from 0.5 to 5 mm.

As indicated in Figure 2, the $X$-parallax error signal is, for small errors proportional to the $X$-component of the relative displace-

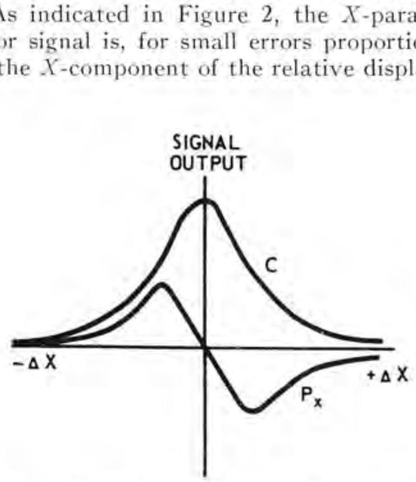


FIG. 2. $X$-parallax and cross-correlation signal for relative $X$-displacement of the scanned areas.

ment of the two areas scanned. It is thus the basic measure of elevation error in the oriented model. In automatic terrain-sensing operation, the computer continuously controls the required model-coordinate motions to maintain a zero value for $P_X$. Electronic gating is employed in the video correlator to reduce the effective scan-size range for elevation measurement to 0.25 to 2.5 mm.

The $Y$-parallax signal represents relative image displacement in the $Y$-direction and is therefore most useful during relative orientation operation. However, after orientation, small residual values are continually removed by adjustment of the air-base components to improve overall correlator operation.

The terrain-slope error signals, $\epsilon S_X$ and $\epsilon S_Y$, indicate residual errors in shaping the scanning patterns to compensate for average terrain slope within the areas scanned. These error signals are used within the computer to update measures of the $X$- and $Y$-terrain-slope components, $S_X$ and $S_Y$, which are used in the scan-shaping process and in plotting-motion generation.

To provide scan-shaping control, the computer generates eight coefficients,

$$\frac{\partial x_1}{\partial X}, \frac{\partial x_1}{\partial Y}, \frac{\partial y_1}{\partial X}, \frac{\partial y_1}{\partial Y}, \frac{\partial x_2}{\partial X}, \frac{\partial x_2}{\partial Y}, \frac{\partial y_2}{\partial X}, \frac{\partial y_2}{\partial Y},$$

which are used by the scan generator section as the coefficients of a first-order transformation of the scanning signals from model to photo coordinates for each photograph. The value of each scan-shaping coefficient is dependent on the local relation between photo and model coordinates, in addition to the terrain slope. For example,

$$\frac{\partial x_1}{\partial X} = \frac{\partial x_1}{\partial X_m} + \frac{\partial x_1}{\partial E_m} S_X$$

The full computation requires 12 partial derivatives of the 4 photo coordinates with respect to the 3 model coordinates. These partial derivatives, which are functions of the photo-model geometry and the model position, are determined by the computer.

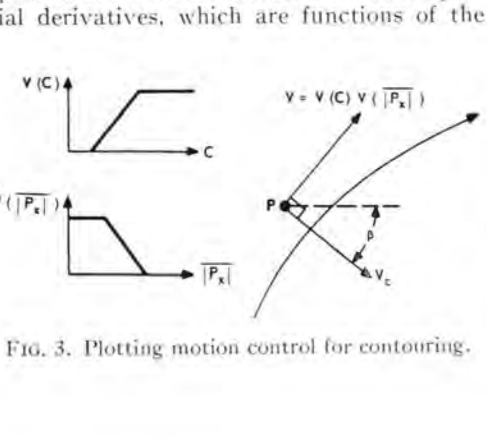


FIG. 3. Plotting motion control for contouring.

PLOTTING-MOTION GENERATION

During contouring and profiling operations, the computer uses the signal outputs of the correlator to generate the required model-coordinate motions. The plotting motions have two components: a command component along the plotting line, and a correction component normal to the plotting line which is proportional to the elevation error indicated by the $X$-parallax. The command component, or plotting speed, is controlled as a function of measured cross-correlation and elevation error to reduce the plotting speed in areas of poor correlation or difficult terrain.

The operation of the system in plotting a contour is indicated in Figure 3. Assume at some instant the instrument has reached a point $P$, which is displaced slightly from the true contour. The command component, $V$, and the correction component, $V_c$, can be considered as velocities, both of which act in directions defined by the angle $\beta$, which is computed as

$$\beta = \tan^{-1}(S_Y/S_X) + \beta' \qquad (1)$$

where

$$\frac{d\beta'}{dt} = K_2 P_X.$$

Assuming for the present that $\beta'$ is small, $\beta$ represents the direction of the local terrain slope as computed from the terrain-slope components, $S_X$ and $S_Y$.

The plotting velocity, $V$, is computed as the product of two functions:

$$V = V(C) \cdot V(\overline{P}_X{}^2).$$

The general form of these two functions is shown in Figure 3. The $V(C)$ function reduces plotting speed under low correlation conditions and stops plotting if the correlation falls below a selected threshold. The $V(\overline{P}_X)^2$ function reduces the plotting speed when mean-square parallax increases above a selected threshold. For large values of parallax, plotting is temporarily halted while the correction component is used to reduce the error to an acceptable level.

The correction velocity, $V_c$, is computed as

$$V_c = K_1 P_X / S_M$$

where $K_1$ is a constant and $S_M$ is the terrain slope magnitude, $S_M = \sqrt{(S_X^2 + S_Y^2)}$. For small values of terrain slope, the value of $S_M$ is limited to avoid division by a near zero quantity.

The most difficult problem in automatic contouring (as in manual contouring) is the control of the plotting motions in areas of very low terrain slope. Referring to Equation 1, it will be noted that as both $S_X$ and $S_Y$ approach zero, the arctangent function in the first term becomes indeterminate. Further, very small errors in $S_X$ and $S_Y$ tend to cause large errors in $\beta$. This difficulty is solved in the AS-11C by use of *parallax integral steering*. The effect of parallax integral steering is indicated in Equation 1 by the correction term, $\beta'$, which is defined in terms of a rate, $d\beta'/dt$, which is proportional to the measured elevation error. The time constants associated with the arctangent term and the correction term are scaled according to terrain slope such that correction term tends to predominate at low slope, whereas the arctangent term is effective at high slopes. Thus, at terrain slopes below a few degrees the plotting direction is defined almost entirely by the parallax error. In areas of small terrain slope, the system tends to plot in a straight line until a small parallax develops and then adjusts the plotting direction accordingly.

In automatic profiling, the plotting velocity is controlled as a function of correlation and parallax in the same manner as for contouring. Profiling is performed at an arbitrary angle $\gamma$ in the $X$-$Y$-model-coordinate plane. (In the orthophoto mode, profiling is performed in the $Y$-model-coordinate direction.) The general equations for profiling operation are:

$$V_X = V \cos \gamma$$
$$V_Y = V \sin \gamma$$
$$V_E = V(S_p + S_p') + K_1 P_X$$

where $S_p$ is the terrain slope in the profiling direction and $S_p'$ is a parallax integral correction analogous to $\beta'$ for contouring. The use of parallax integral steering is not as essential for profiling as for contouring; however, it does result in smoother operation in areas where terrain-slope information is poor.

### ORTHOPHOTO OUTPUT EQUIPMENT

The orthophoto equipment consists of the video printer unit, printing control logic, the video processor, and the hypsocline contour generator (See Figure 1).

As may be noted from the Frontispiece, the printer is a modified AS-11C viewing unit, containing similar CRT assemblies, CRT optics, and precision servo-driven photocarriages. The upper housing of the printer provides facilities for loading and removing recording film under normal room lighting. The recording films are held by vacuum in a horizontal plane upon the photocarriages. The orthophoto is printed on one carriage and the hypsocline contour chart is printed simultaneously on the other.

Each image is compiled as an assembly of incremental images which are generated in scaled model coordinates on the faces of the respective printing CRT's and are transferred optically to the film. The printer film carriages are driven in $Y$ and indexed in $X$ by model-coordinate commands transformed to the orthophoto scale by the computer. The operation of the printer in a scaled $X$-$Y$-model-coordinate system with video signals generated by scanning in the photocoordinate system provides the basic image transformation required for orthographic compilation. In this process, the elements of imagery appearing in the orthophoto are rectified to compensate for camera geometry and orientation, and shaped to eliminate effects of terrain slope and elevation change within the model.

The incremental printing exposures are produced by a special printing-scan pattern, which is time-shared with the normal correlation scan pattern. The print pattern is generated as a progression of parallel scan lines, oriented in $X$, with a line-spacing equal to the 5-micron diameter of the scanning-spot. The $X$-dimension of the pattern is equal to the selected profile interval, and the $Y$-dimension or print height is normally selected between 1/3 to 1/6 of the $X$-dimension.

During compilation, the system operates with the correlation scan pattern until the printer $Y$-carriage travels a distance equal to the print height. The printing control logic then interrupts the correlation pattern, turns on the printing CRT's, and generates one print pattern. At the end of the print cycle, the correlation scan resumes and continues until the next print command. The correlator derives information from both scan patterns, and plotting motions during printing are continuous. The plotting speed and correlation scan size remain variable, controlled by $X$-parallax error and cross-correlation.

The video processor provides electronic gating, control of exposure, and amplification as required to drive the orthophoto printing CRT. Because of the high electrical frequencies contained in the video signals, the video processor and associated video controls are located in the printer unit. The remainder of the printing control circuits are housed in the orthophoto controller. The controller cabinet also contains the scan-generation and time-sharing circuitry which is special to the orthophotoscope operation, and the hypsocline contour generator.

The hypsocline contour generator operates from elevation and terrain-slope information supplied by the computer to generate a video signal representing the contour locations within the printing-scan pattern. The hypsocline chart is compiled as an assembly of such patterns in the same manner as the orthophoto.

The hypsocline video signal is generated as a series of pulses, with the center of each pulse occurring at the point in time at which an instantaneous elevation signal coincides with a contour elevation. The instantaneous elevation signal, $E_I$, is scaled according to the selected contour interval and is generated as follows:

$$EI = (E_M/I) + X(S_X/I) + Y(S_Y/I)$$

where

- $E_M/I$ is the model elevation with respect to the nearest contour elevation, normalized according to the selected contour interval,
- $X$ and $Y$ are the scaled model-coordinate scan signals,
- $S_X/I$, $S_Y/I$ are the normalized terrain-slope signals.

As the instantaneous elevation signal is referenced to the nearest contour elevation, the instantaneous conditions $E_I = 0, \pm 1, \pm 2 \ldots$ represent the times at which the scan signal crosses a contour line. These conditions are detected by five separate comparison circuits which are referenced to the elevation levels $-2$, $-1$, $0$, $+1$, $+2$. Thus, under conditions of large terrain slope or small contour interval, the contour generator can plot up to five contours within one scan pattern.

The contour generator also contains provisions for emphasizing every fifth contour. An emphasis signal, derived from the model-elevation signal in the computer, is used to increase the printing intensity of the video signal pulses which correspond to emphasis contours.

Figure 4 indicates the major characteristics of the hypsocline contour output. As the contour information is derived from average terrain-slope information, the contours are straight-line segments of constant spacing

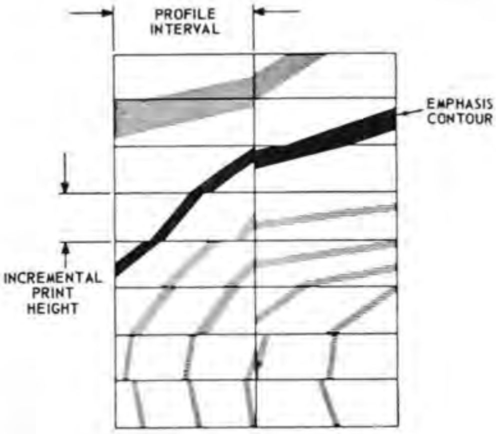


FIG. 4. Form-line contour characteristics.

within each printing scan pattern area. Also, the width of the line varies as a function of terrain slope, increasing in width with decreasing slope, according to the fractional value of elevation change represented by the sensitivity of the comparison circuits. The sensitivity band of the comparators can be adjusted to vary the relative contour line width from 5 to 50 percent of the contour interval.

## Operating Characteristics

All orientation and compilation operations of the AS-11C system are performed within five operating modes: orientation, contouring, profiling, orthophoto, and fill-in. These modes are distinct in that they require that different computational and control functions be performed by the computer.

Initial set-up procedures are common to all operational modes. The photographs are mounted in the viewer, and main program and initial-condition tapes corresponding to the camera, geometry, and focal-length range are read into the computer. Interior orientation is then performed by measurement of the fiducials, and the computer automatically computes and stores the photo principal-point locations. A control-program tape is then entered to establish operation in the desired operating mode.

### Orientation Mode

The orientation mode provides relative and absolute orientation of the stereo model. This mode is employed when a given stereo pair is being processed for the first time. If the model has been previously oriented, it can be re-

FIG. 5. Section of an AS-11C contour chart.

covered by reading a tape which contains the orientation parameters.

In relative orientation, the values of the camera focal length and the correction coefficients are first entered from the viewer panel. The orientation errors are then determined from measurements of $Y$-parallax made automatically at from 5 to 12 points in the model. At each point, the correlator outputs are used by the computer automatically to eliminate the elevation error and $Y$-parallax. The $Y$-parallax is eliminated by inserting a differential $y$-displacement of the two photographs. During this process, the amount of motion required is recorded as the $Y$-parallax. After these measurements have been made at the desired points, the computer calculates and stores in appropriate locations the necessary changes in the values of the orientation elements.

Absolute orientation is based on the known model coordinates of three or more control points. The known coordinates of each point are sequentially entered through the viewer panel while the corresponding coordinates in the unoriented model are being measured, using the correlator outputs to clear the elevation error. When this procedure is completed, the computer determines the required changes in the orientation elements to level and scale the model. If more than three control points are used, the leveling and scaling computations minimize the mean-square errors at all control points. If desired, the residual errors at the control points can then be used to define the coefficients of the model-deformation correction.

CONTOURING MODE

The contouring mode produces conventional contour manuscripts that are automatically plotted on the coordinatograph. To initiate operation, the contouring mode control program tape is entered, and quantities defining the desired contour interval, plotting boundaries, and output scale are entered from the viewer panel.

Automatic plotting may be initiated at any desired elevation. Plotting proceeds automatically along a contour line until the contour closes upon itself or intercepts a model or photo boundary. When one of these occurrences is detected by the computer, the plotting stylus is raised and the model elevation is automatically adjusted to the next contour elevation value. The plotting stylus is then lowered and plotting is resumed.

As noted in an earlier section, the plotting speed is automatically controlled as a function of measured cross-correlation and $X$-parallax errors. Also, if the parallax error values exceed predesignated limits, the stylus is raised until acceptable error limits are regained. If correlation falls below an acceptable value, the stylus is raised and the computer commands a local search to re-establish the plotting line at some nearby point. The coordinates of the end of the gap, i.e., the point at which automatic plotting is resumed, are automatically recorded for use during later manual fill-in operations.

An example of the automatic contouring output, before manual fill-in or editing, is shown in Figure 5. The section shown is approximately at output plotting scale,

FIG. 6. Section of an AS-11C orthophoto—Canberra, Australia.

1:24,000. The contour interval is 50 feet. The input materials are from the Fort Sill area of Oklahoma, and the photo scale is 1:48,000.

PROFILING MODE

The automatic profiling mode produces profile charts which are automatically drawn by the coordinatograph for any selected profiling direction within the model. To initiate operation in this mode, the profiling-mode tape is entered, and the desired profile direction, profile interval, coordinatograph index offset, plotting boundaries, and output plotting scale are entered from the viewer panel. Automatic profiling can be started at any point in the model. The detailed operation in profile compilation is similar to that for contouring except that automatic indexing is performed only at the plotting boundaries.

ORTHOPHOTO MODE

In the orthophoto mode, orthophotographs and hypsocline charts are compiled on photographic film on separate stages in the printer. Examples of orthophoto and hypsocline contour outputs are shown in Figures 6, 7, and 8. Figure 6 is a 1:80,000 orthophoto of Canberra, Australia, compiled with 5-mm profiles. Figures 7 and 8 are of the same model area shown in Figure 5; they were compiled with an output profile of 2.5 mm.

To initiate operation, the orthophoto-mode tape is entered, and the desired values for the profile interval, model boundaries, output plotting scale, contour interval, and contour reference elevation are entered from the viewer panel. Orthophoto compilation is started in one corner of the plotting area. Profiling is performed in the $Y$-direction, with the $X$-direction indexing at the plotting boundaries. In regions which are not plotted, the coordinates of both ends of the gap are recorded for later use in fill-in operations.

The video signal for the orthophoto is normally selected from the photograph whose nadir point is nearest to the compilation point. This procedure improves resolution and minimizes local image distortion in the output orthophoto. Automatic switching from one video signal to the other is performed by the computer at the mid-point of the air base. Dual sets of video controls are provided to compensate for differences between input photo densities and to unify the output density characteristics of the orthophoto across the transition region. In Figure 7, the transition of video information from Photo 1 to Photo 2 is evident from the different position of the reseau patterns on the input photographs.

FIG. 7. Section of an AS-11C orthophoto—Fort Sill.

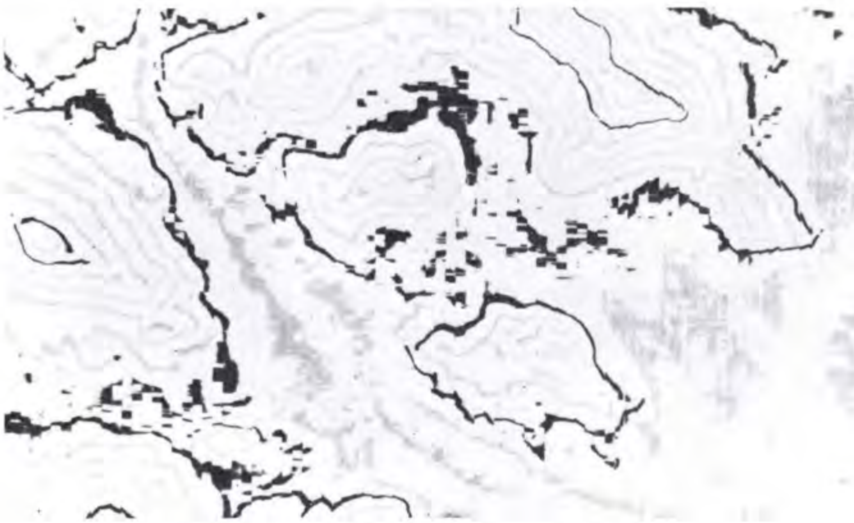

FIG. 8. Section of an AS-11C hypsocline—Fort Sill.

FILL-IN MODE

As discussed in the preceding sections, those portions of the model that contain insufficient or uncorrelatable image information are left unplotted and their locations are automatically recorded when correlation is regained. In the fill-in mode, the gaps created by this procedure are plotted manually to complete the output record.

Fill-in is usually performed immediately after completion of the automatic compilation. The fill-in program is entered into the computer, and the fill-in coordinate record tape is placed on the tape reader. At operator command, the computer sequentially reads the coordinates of each gap and positions the floating mark at the point where automatic plotting was resumed. For fill-in of automatic contour and profile records, the operator plots across the missing portions of the compilation, observing completion of the coordinatograph. During orthophoto fill-in, where the output compilation is not visible, travel during printing is restricted by the computer between the start and end points of each gap. The computer controls the $Y$-motion in traversing the gap, while the operator controls elevation. At the option of the operator, the computer automatically controls elevation across the gap as a linear interpolation between the recorded elevations at the end points. If desired, the hypsocline contour generator can be turned off during manual fill-in.

### Conclusion

The automatic contouring and profiling modes of the AS-11C represent a significant expansion of the AS-11A system capabilities. Automatic contouring enhances the stereoplotter's basic function of compiling high-resolution topographic information. In the AS-11C, automatic contouring is performed at the same level of accuracy as in the AS-11A, the plotting speed is substantially increased, and the operator is released from routine plotting operations.

The orthophoto mode provides a high-speed method for extracting planimetric information from the stereo model. The speed of this operation is enhanced by the capability to transfer imagery over a wide profile interval, with resolution and metric accuracy sufficient to allow the outputs to be compiled at scales substantially larger than photo scale. The hypsocline contour chart, produced in the orthophoto mode, provides a substantial time saving in situations where high-resolution topographic information as produced by conventional contouring is not required.

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