CHAPTER 12

Some more Instruments

This book has so far been mainly concerned with imparting an understanding of the theory of making maps from air photographs; but in this chapter we intend to introduce the reader to some of those plotting instruments which he might expect to encounter in large-scale commercial production.

One method of grouping machines is by reference to the traditional land-surveying criterion of accuracy of work. Planimetric accuracy might be a useful measure with regard to planimetric plotting alone but other factors must be considered in a general classification. Schwidefsky classifies as first order, only those instruments which are capable of both detail plotting and aerotriangulation. Such instruments are often known as universal, though this term sometimes implies that the instrument is also capable of plotting from oblique or ground overlapping photographs. Although universal in the former sense, the multiplex is only a second-order machine since it lacks the necessary accuracy. The Stereoflex and Stereotope would be classified as third-order machines.

One of the oldest of photogrammetric instruments is the stereo-comparator (see Fig. 12.1). In its simplest form this instrument consists essentially of a mirror stereoscope and magnifiers, incorporating a pair of half-marks or grids. The spatial coordinates of the floating mark can be accurately read. Corrections for model distortion must be computed, a procedure which was formerly extremely tedious. The instrument can thus be used to increase the amount of control mathematically, i.e. to achieve an "analytical" aerotriangulation. Analysis of the distortions in the base materials is assisted if a réseau is incorporated in the taking camera. It can also be used for non-cartographic photogrammetric analysis; but it is not a plotting instrument.

Plotting instruments also may be linked with electronic computers, and a point may be plotted and its coordinates enumerated at the same time.

Most of the major manufacturers produce at least one model which can be considered as first order. In Britain perhaps the best-known first-order machine is the Zeiss Stereoplanigraph (see Fig.

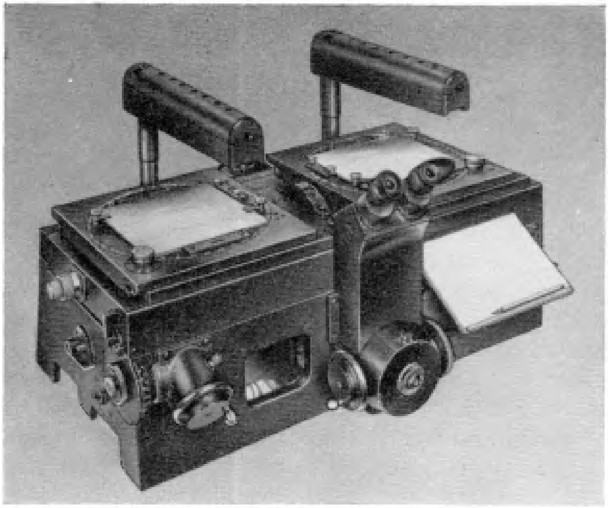

FIG. 12.1. A STEREOCOMPARATOR
(*Zeiss Jena*)

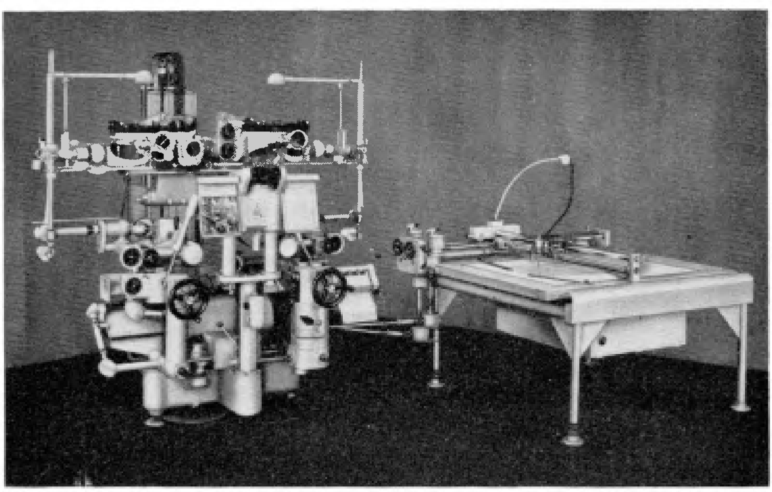

FIG. 12.2. THE STEREOPLANIGRAPH
(*Zeiss Aerotopo*)

12.2), while the best-known range comprises the Wild A7 (see Fig. 12.3), A8 (see Fig. 12.4), A9 (see Fig. 12.5), A10 (see Fig. 12.6) and B8 (see Fig. 12.7).

In considering the order of an instrument, we have spoken of accuracy, by which we mean position accuracy and heighting accuracy. The latter is usually considered in terms of the *C*-factor, where $C = \frac{H - h}{V}$, *V* being the minimum contour interval attainable in the given circumstances.

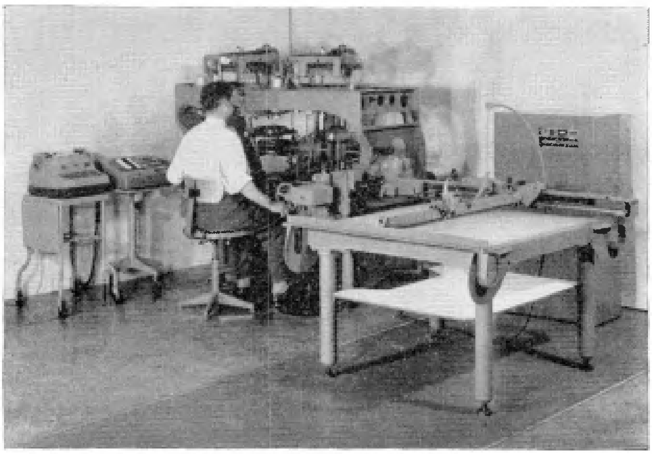

FIG. 12.3. THE A7 AUTOGRAPH
(*Wild Heerbrugg Ltd.*)

Referring back to the calculation for maximum flying height in a previous chapter, we found that for a 15 m V.I. the maximum flying height was 4,735 m. Since the mean height of the ground above datum was 135 m, the C-factor for those simple methods would be

approximately $\frac{4{,}735-135}{15} \simeq 300.$

The classification for each plotting instrument includes an assessment for *C*-factor, but too much importance must not be attached to this factor since many extraneous circumstances may affect the heighting accuracy, e.g. after a series of tests two equally experienced operators may allot quite different *C*-factors to the same instrument, and in testing two different types of machine *A* and *B*,

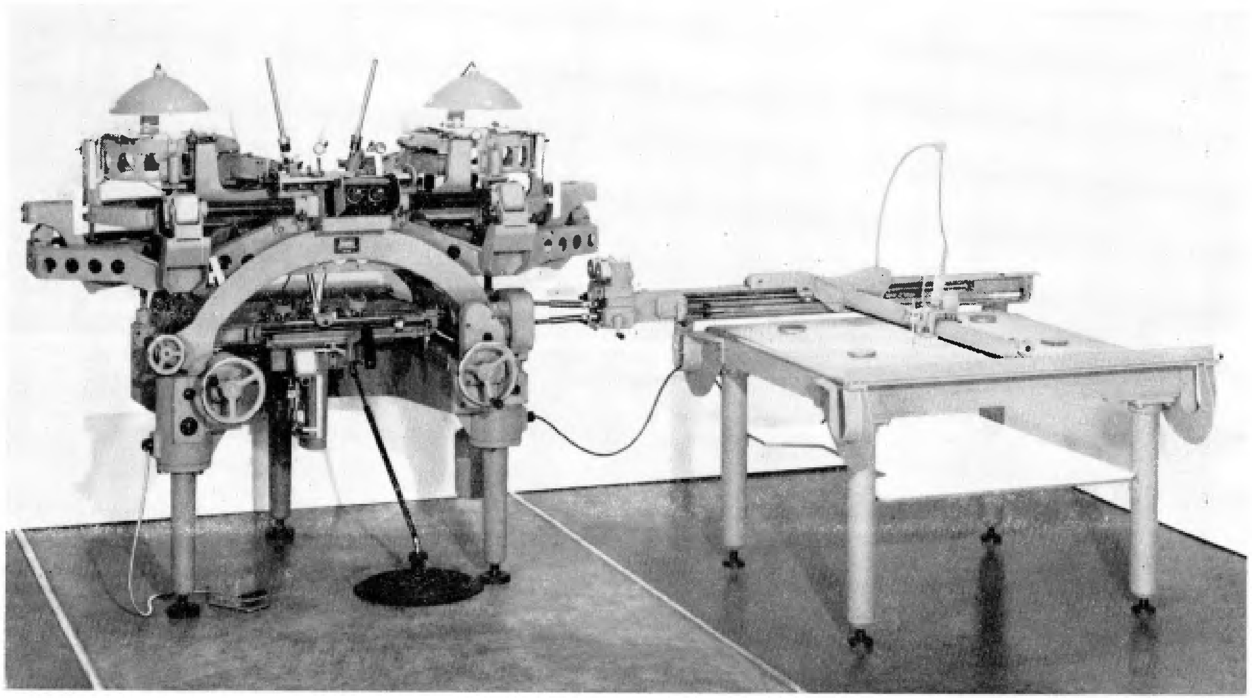

FIG. 12.4. THE A8 AUTOGRAPH
(*Wild Heerbrugg Ltd.*)

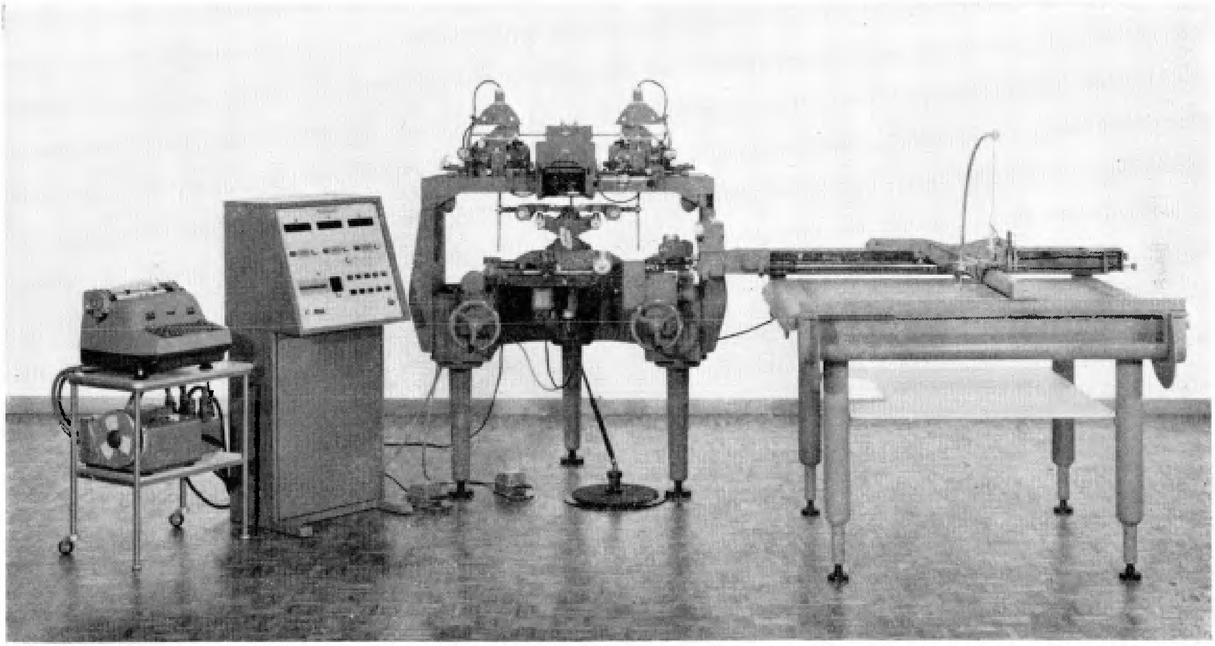

FIG. 12.5. THE A9 WIDE-ANGLE AUTOGRAPH WITH EK8 COORDINATE PRINTER, IBM TYPEWRITER (INPUT/OUTPUT WRITER) AND SL15 TAPE PUNCH (*Wild Heerbrugg Ltd.*)

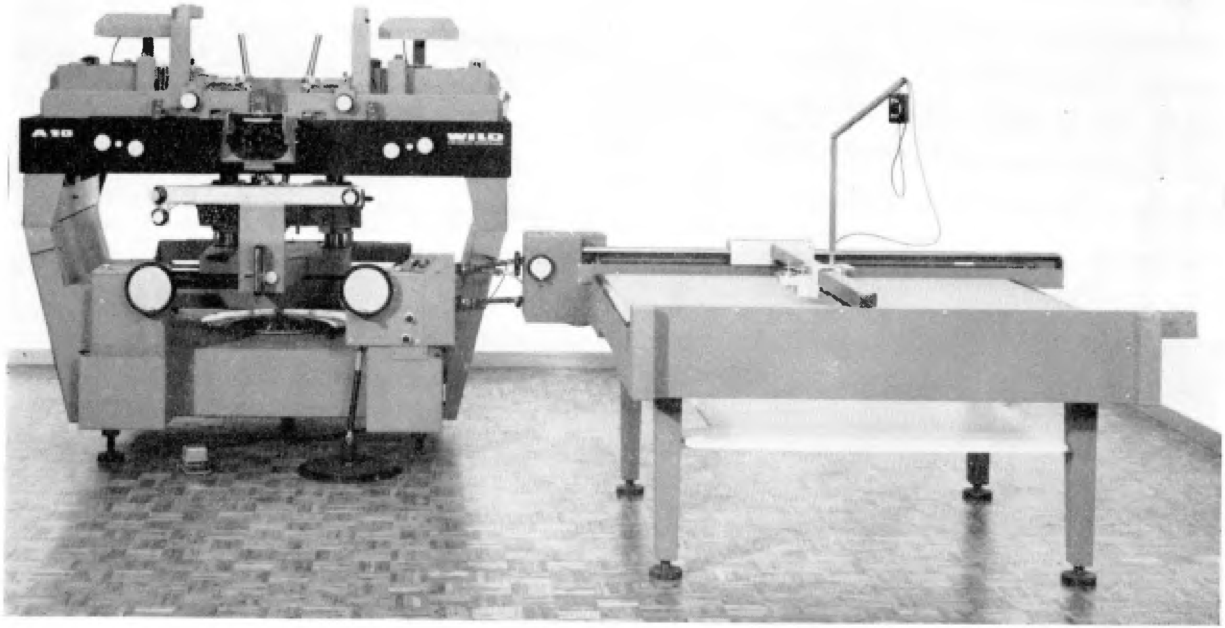

FIG. 12.6. THE A10 AUTOGRAPH
(*Wild Heerbrugg Ltd.*)

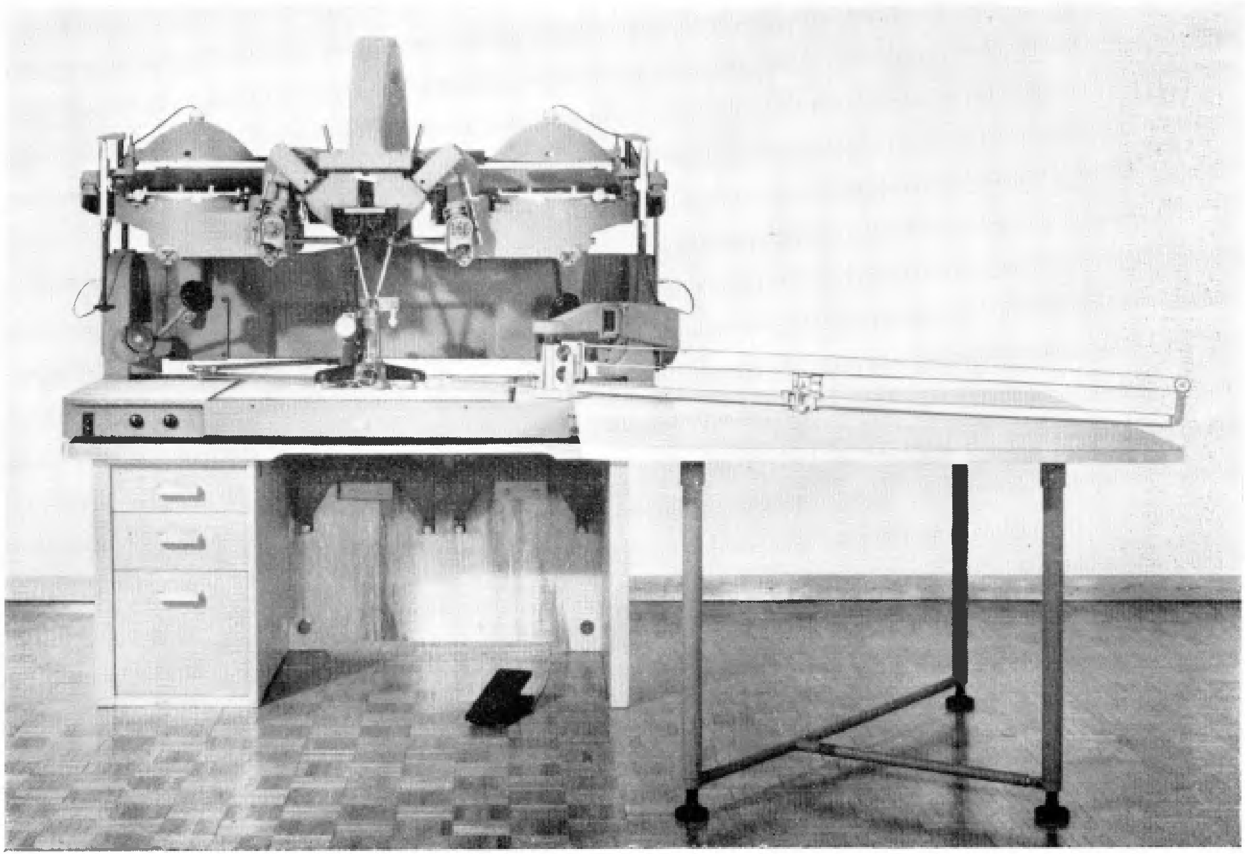

FIG. 12.7. THE B8 AVIOGRAPH
(*Wild Heerbrugg Ltd.*)

the first operator might allot machine *A* the higher *C*-factor, while the second operator might allot the higher factor to instrument *B*. This difficulty is brought out by the fact that *C*-factors allotted to the multiplex vary at least between 600 and 1,000. This range is incidentally barely higher than that attainable by most of the modern third-order instruments. The Balplex 525 has a working *C*-factor of 800–1,500.

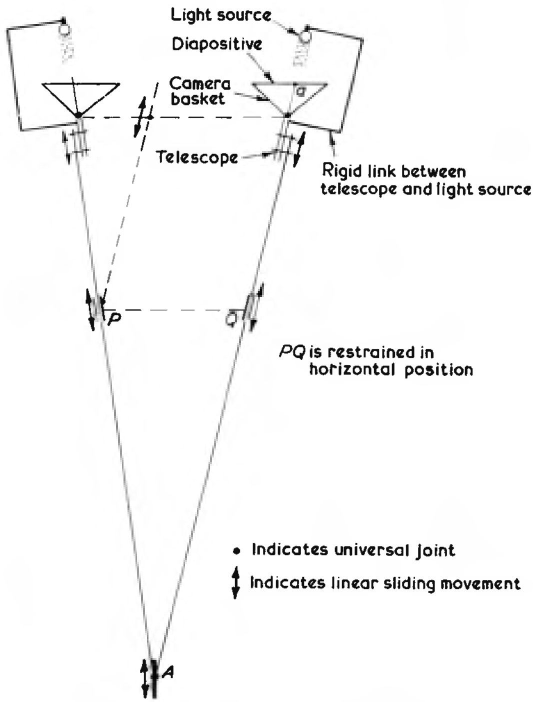

FIG. 12.8. SIMPLIFIED SKETCH DIAGRAM TO SHOW THE MOVEMENT OF A SYSTEM OF SPACE RODS

The *C*-factor is not usually applied to simple methods involving the parallax bar.

The Stereoplanigraph is often said to be representative of the purely optical group of instruments in which images from the diapositives are projected and the reflected images are viewed stereoscopically. It is sometimes also called a Porro–Koppe type of instrument, although the lens distortion is now removed by a glass correction plate; a separate plate is used to " pair " with each range of taking cameras.

The Wild Autographs are similarly said to be representative of the optical-mechanical group of instruments in which prints or dia-positives are viewed stereoscopically through a pair of telescopes. Each telescope pivots about a mechanical centre which takes the place of the optical centre of the viewing "camera basket," and is linked with a rod whose movements therefore follow those of the

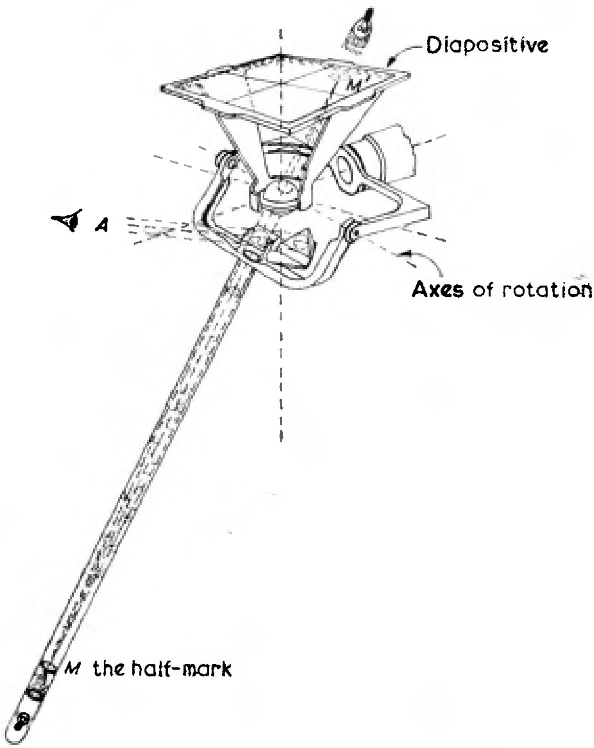

FIG. 12.9. THE VIEWING SYSTEM IN THE NISTRI PHOTOSTEREOGRAPH MODEL BETA/2
(*Ottica Meccanica Italiana*)

half-mark. These are the space rods, which in the simplest conception (see Fig. 12.8) can be considered as intersecting in the space position A, of the floating mark. The pencil at A is so far below the camera baskets that the resulting instrument would be excessively tall. The mechanism shown by the broken lines in Fig. 12.8 would shift the effective plotting point to pencil P. This is sometimes

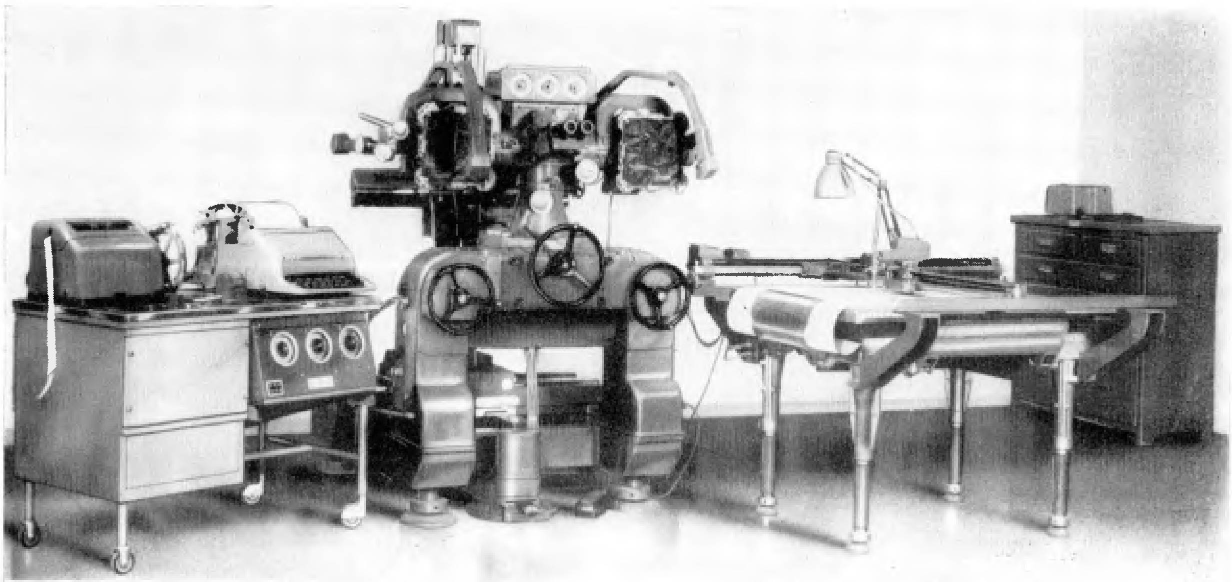

FIG. 12.10. THE PHOTOSTEREOGRAPH (BETA/2) COUPLED WITH COORDINATE COMPUTER ON THE LEFT AND PLOTTING TABLE AND COORDINATE PLOTTER ON THE RIGHT
(*Ottica Meccanica Italiana*)

known as the Zeiss parallelogram. The plotting scale would be reduced but the pencil at P could be replaced by a horizontal pantograph.

Figure 12.9 shows the way in which the images of photo and half-mark are viewed in the first-order Nistri machine shown, in Fig. 12.10, set up between a coordinate recorder on the left, and an electric coordinatograph and plotting table on the right.

The Thompson-Watts plotter, a British machine, is one of the most accurate instruments for numerical aerial triangulation and plotting, but is no longer produced.

In both the A7 and A8, the model is correctly re-formed, but the A7 is first-order, and the A8 is second-order because, although little less accurate than the A7, it is not universal.

THE WILD RANGE OF PLOTTING INSTRUMENTS

The A8 Autograph

Basically the A8 (Figs. 12.4 and 12.11) comprises two camera-lucidas into which a pair of diapositives are inserted, and viewed stereoscopically. The cameras are oriented as would be the corresponding pair of multiplex projectors. The sight-lines are represented by a pair of space-rods rotating about perspective centres S_1 and S_2, and meeting in a point A (Fig. 12.11) which is free to trace out the spacial model formed by the points being viewed. The horizontal position of A is conveyed to an adjacent plotting table by a system of linkages, and the relative height of A can be read out on a height scale similar to that of the multiplex.

For ease of description we will consider the A8 as comprising the the following parts (see Fig. 12.11)—

A. the sub-structure with
   1. the X-, Y- and Z-carriages
   2. the space rods

B. the superstructure with
   3. the camera complex
   4. the lazy-tongs linking the telescopes' movements with those of the space-rods
   5. the viewing telescopes and the optical trains

C. the plotting table with
   6. the plotting pencil
   7. the linkage between carriage complex and plotting table.

Where there are similar right-hand and left-hand units, it will normally be the right-hand unit which is described.

The substructure is the rigid base of the instrument, which is carried on three adjustable legs. The rigid arched portion (Fig. 12.4) is known as the yoke and is supported by the flat tabular part to which the carriage complex is also attached.

1. The *X*- *Y*- and *Z*-carriages. Right in the middle of the instrument, and just above the knees of the operator, is the carriage complex, similar in purpose to that of the Stereomicrometer.

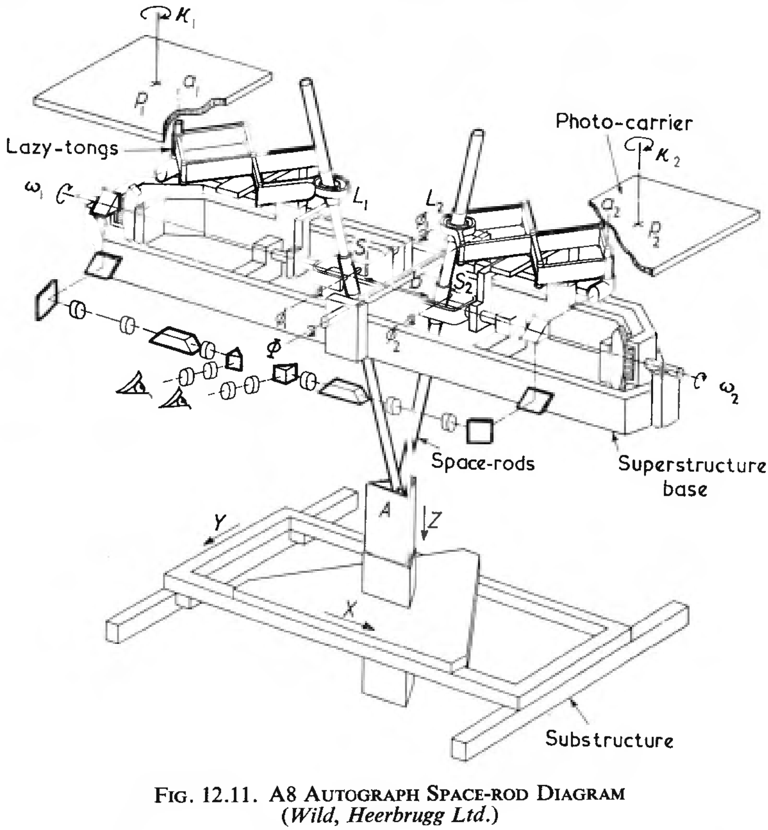

FIG. 12.11. A8 AUTOGRAPH SPACE-ROD DIAGRAM
(*Wild, Heerbrugg Ltd.*)

The *Y*-carriage is mounted on rails which are rigidly attached to the substructure. It is free to move only in the *Y*-direction, that is in the front-to-back direction of the instrument, which will later be seen to be the lateral direction of the line of flight of the observed model. The carriage is moved along its rails by turning the large right-hand handwheel (Fig. 12.4).

The X-carriage is mounted on rails attached to the Y-carriage. It is free to move relative to the Y-carriage only in the X-direction, that is in a horizontal direction perpendicular to the Y-direction. This is the fore-and-aft direction of the model, and the movement is operated by the large left-hand handwheel.

Mounted in the X-carriage, and free to move only in the Z, or up-and-down, direction is the Z-carriage. This carriage is moved by rotating the foot-disc (see Fig. 12.4) with the right foot.

The foot of each space-rod is attached to the Z-carriage by a universal joint, A in Fig. 12.11. A is thus free to be moved in three perpendicular directions.

There is an X-scale, a Y-scale and a Z-scale, which indicate the movements of the three carriages, and enable a visual readout of the three spacial coordinates of A. The Z-scale is the height-scale or -index; it is similar to that of the multiplex tracing table, and for wide-angle photography it has a range of from 175 to 280 mm. The height-index actually forms part of the X-carriage, and so does not itself move up and down.

Just above and to the front of the top of the foot-disc spindle is a grip-release handle (seen black in Fig. 12.4). When the handle is gripped a lever is depressed, and this releases the X- and Y-carriages so that they may be moved freely without using the handwheels. When the grip is relaxed these carriages are again moveable only by the handwheels.

2. The space-rods represent the lines of the perspective rays in space, and as they meet at A, which traces out the three-dimensional model of the ground surface, then A also represents the point which is under observation at any particular moment. Each rod is free to slide through a sleeve which in turn is free to rotate in its universal joint at S_1 or S_2 (Fig. 12.11). These two points represent the perspective centres and the distance between them, b, can be varied to set the scale of the model before plotting begins. There is a second sleeve on each rod which is free to rotate about L_1 or L_2. These points are the centres of universal joints attaching the rods to the lazytongs.

The superstructure is carried on a base-frame, and comprises that part of the instrument which carries the cameras. It is so constructed as to enable the cameras each to rotate about its ϕ-, ω- and κ-axes, to rotate jointly about the Φ-axis, and to be capable of an adjustment to accommodate a range of different principal distances. The frame itself is seen in Fig. 12.11; it is the part which extends beyond the substructure at both sides in Fig. 12.4. The Φ-axle rotates on the apex of the yoke, and this movement is controlled by the small left-hand handwheel (Fig. 12.4).

3. The camera complex (Fig. 12.12) contains a camera lucida which is flooded with light from above by means of a 35-watt lamp in a parabolic reflector housing. The diapositive, or negative, is mounted on to a detachable picture carrier, which is inserted into the camera

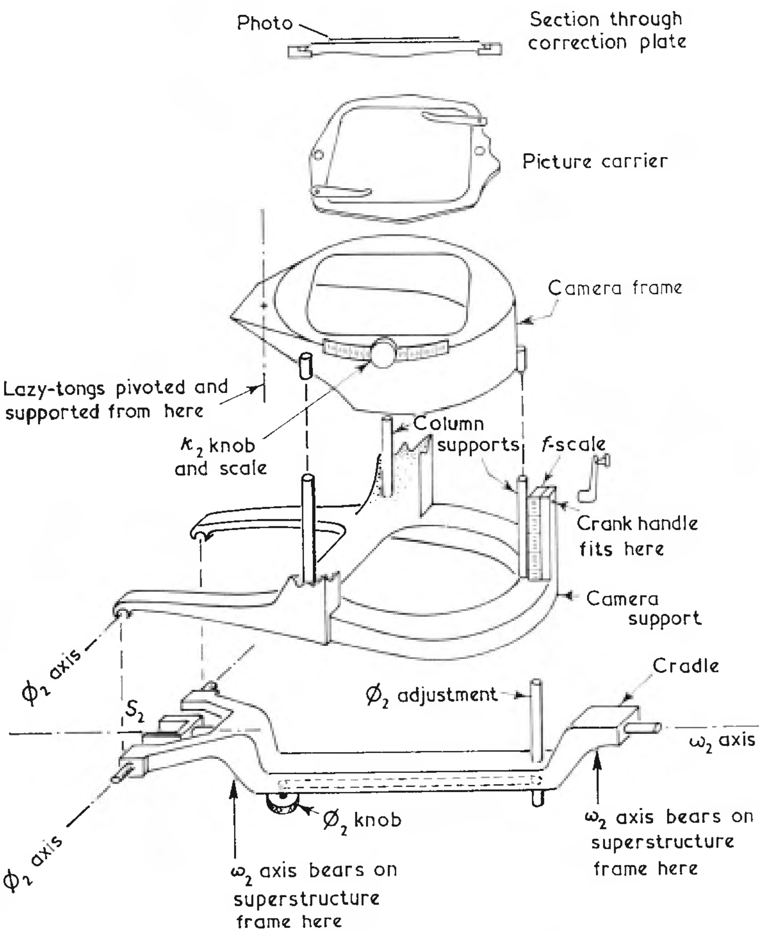

FIG. 12.12. WILD A 8 CAMERA COMPLEX D

frame and is rotatable in swing by means of the knob at the top front of the frame. The picture carrier consists of a metal frame surrounding a sheet of optical-quality glass on which calibrating marks are engraved. For greater accuracy this glass may be replaced by a glass correction plate, shown in section in Fig. 12.12(i). The correction plate is optically designed and ground to offset the lens distortions of the taking camera, and if desired may also include a correction for earth curvature. It may be designed to balance the distortions of one particular lens or to be complementary to a range of lenses. The camera frame is mounted on the camera support by means of three variable columns. The angular relationship between the frame and the support is constant; but the "vertical" distance between the two can be varied by adjusting the height of the column supports. The movement of these columns is linked, so that rotation of the detachable crank-handle causes all three to be raised or lowered simultaneously and by the same amount. This is the way in which the focal length is set.

The camera support is mounted in the cradle so that it rotates about the ϕ_2-axis of the cradle. This movement is achieved by turning the ϕ_2-knob (see Fig. 12.12). The camera cradle is a rigid framework of which the ω_2-axis of Fig. 12.11 forms a part. It is free to be rotated about this ω_2-axis by means of a knob which may be found above the eye-piece and in front of the space-rods.

4. The lazy-tongs (Fig. 12.11) are sometimes called the scissors, double scissors or double rhomboids, and are supported in a horizontal position at their central pivot by the camera frame. They carry the telescope, a_2, at one end, and the universal joint, L_2, at the other. This ensures that the lazy-tongs and telescope move only in a plane parallel with the plane of the diapositive, and allows the axis of the telescope to be maintained perpendicular to the plane of the diapositive. The central pivot remains stationary relative to the diapositive, whilst the movements of the telescope are the reciprocal of those of the point L_2. As L_2 moves towards the operator so the telescope moves away by an equal amount, and as L_2 moves to the left so the telescope moves to the right. This means that as the distance between the two telescopes, a_1 and a_2, increases so the distance between L_1 and L_2 decreases and the position of A is lowered. If we look again at Fig. 6.2 we shall see that as the parallax increases, so the model height increases, thus A is rising and falling in sympathy with the visual model.

It can now be seen that the focal length adjustment has the effect of raising and lowering the diapositive, together with the lazy-tongs and L_2, relative to the camera support. The vertical distance between L_2 and S_2 is therefore altered, and this distance represents the principal distance in the space-rod perspective diagram.

The viewing telescope contains the half-mark, and the images of the diapositive and the half-mark are together conveyed by a flexible optical train (shown in Fig. 12.11) from the telescope to the eye-piece in the centre front of the instrument. The diapositives are thus viewed from below; but since they are placed emulsion side down on the picture carriers and are arranged with their common overlap nearest to the instrument centre-line (the Φ-axis), the model conveyed to the eyes will be erect as it is in the mirror stereoscope.

The operator can therefore sit facing the instrument, and look through the eye-piece at the three-dimensional model of the ground. By moving the *X*- and *Y*-handwheels he can scan the whole overlap, and by adjusting the foot-disc he can raise and lower the apparent position of the fused dot so that it lies at ground level on the model.

The plotting-table is essentially a flat horizontal ground-glass surface, usually one metre square. The plotting surface must be maintained level by adjusting the length of the legs to bring the two bubbles of a cross-level to the centres of their runs. The base-grid is mounted on the table surface, and plotting is done by a coordinatograph whose pencil can be raised and lowered by means of the left-foot pedal (see Fig. 12.4).

The coordinatograph consists of a straight cantilever arm mounted at right angles to a straight rail, along which the supporting end of the cantilever moves. The pencil is mounted on the cantilever arm along which it is free to run. Thus the pencil is free to move in two mutually perpendicular directions, which represent the coordinate directions of the instrument.

A series of spindles, worms, gears and splines are assembled to drive the pencil in the *X*- and *Y*-directions in sympathy with the horizontal movements of the universal joint, *A*. A range of 7 gear ratios are fitted so that the movements of the pencil may be set to any of a series of 15 magnifications relative to the space-rod model, ranging from 1:4 to 4:1. A profiloscope may be fitted to the plotting point to enable the operator to see, by reflection, the plotting table in the vicinity of the plotting pencil, without moving his position relative to the instrument.

The Operation of the Instrument

The A8 is a precision instrument and must be installed in a stable position free from vibrations of all kinds. A solid ground floor would be considered essential. It must be maintained free from dust, and the moving parts must be regularly lubricated in accordance with the maker's instructions. The *X*- and *Y*-carriages must be kept perfectly horizontal by adjustment of the three legs.

A mapping project with the A8 must be planned in the same way as any other such project. The manufacturers suggest that a mean photo scale should be calculated in accordance with the following equation—

$$m_B = c\sqrt{m_K}$$

where m_B is the reciprocal of the photo scale, m_K the reciprocal of the required map scale, and c is a constant which varies between 200 and 300 according to the severity of the demands for accuracy, the lower figure being chosen for the severest demands. Thus suppose that the required mapping scale was 1/2,500, and the demands for accuracy were moderate, then

$$m_B = 250 \times 50 = 12{,}500$$

The scale of the photography should then be 1/12,500 and the flying height for a 150 mm lens would be $\frac{150 \times 12{,}500}{1{,}000} = 1{,}875$ m.

Choice of Instrument Scale

When plotting is about to begin a choice must be made regarding the glass scale to be inserted in the height index, and the appropriate gear-ratio for connexon with the plotting table. There are three separate scales with which we are concerned—the scale of the photographs, the map (or plotting) scale, and the scale of the instrument model. We have seen how, in the multiplex, the scale of the model is set by the X-separation of the projectors; this separation represents the base-length, S_1S_2. Similarly the scale of the space-rod model of the A8 can be set by adjusting the base-length (b in Fig. 12.11). This separation of S_1 and S_2 can be altered by rotating a handle, which can be seen in Fig. 12.4 at the right-hand end of the horizontal shaft behind the eye-piece. Since the relationship between the instrument scale and the map scale must equate to one or other of the gear-ratios provided, it is this b-adjustment which must be used to remove any residual error between the instrument scale and the photo scale.

The height scale sets the instrument model scale, and we have a choice of 15 different glass scales which enable a read-out of heights in metres. To save calculation, the manufacturers produce tables which enable the choice to be made without actual calculation (see Table 7). Thus, choosing the largest scale consistent with a flying height of 1,750 m, we see that we need the 1/7,500 glass scale, and for plotting at 1/2,500 from a 1/7,500 model we need a gear-ratio of 1:3.

Orienting the Instrument

Inner orientation. As with the multiplex, the purpose of inner orientation is to re-establish the same relationship between lens and photo plane as existed at the time of exposure.

Table 7

WILD A8: EXTRACT FROM SCHEDULE OF GLASS SCALES

(Wild Heerbrugg Ltd.)

Flying height above ground, wide angle, max.	Flying height above ground, wide angle, min.	Glass scale 1/	Plotting scale 1/ 1000	1500	2000	2500	3000	4000	5000	6000
840	530	3000	1:3	1:2	2:3	5:6	1:1	4:3	5:3	2:1
1050	650	3750		2:5		2:3	4:5		4:3	8:5
1120	700	4000	1:4	3:8	1:2	5:8	3:4	1:1	5:4	3:2
1400	880	5000		3:10	2:5	1:2	3:5	4:5	1:1	6:5
1680	1050	6000		1:4	1:3		1:2	2:3	5:6	1:1
2100	1300	7500				1:3	2:5		2:3	4:5
2240	1400	8000			1:4		3:8	1:2	5:8	3:4
2800	1750	10000				1:4	3:10	2:5	1:2	3:5
3350	2100	12000					1:4	1:3		1:2
3500	2200	12500							2:5	
3700	2350	13333						3:10	3:8	
4200	2650	15000							1:3	2:5
4650	2900	16667							3:10	
5600	3500	20000							1:4	3:10
7000	4400	25000								
8400	5300	30000								
10500	6500	37500								
11200	7000	40000								
Heights in metres										Gear

Table 7—(continued)

7500	8000	10000	12000	12500	15000	18000	20000	24000	25000	50000
5:2	8:3	10:3	4:1							
2:1		8:3		10:3	4:1					
	2:1	5:2	3:1							
3:2	8:5	2:1		5:2	3:1		4:1			
5:4	4:3	5:3	2:1		5:2	3:1	10:3	4:1		
1:1		4:3	8:5	5:3	2:1		8:3		10:3	
	1:1	5:4	3:2				5:2	3:1		
3:4	4:5	1:1	6:5	5:4	3:2		2:1		5:2	
5:8	2:3	5:6	1:1		5:4	3:2	5:3	2:1		
3:5		4:5		1:1	6:5		8:5		2:1	4:1
	3:5	3:4					3:2			
1:2		2:3	4:5	5:6	1:1	6:5	4:3	8:5	5:3	10:3
		3:5		3:4			6:5		3:2	3:1
3:8	2:5	1:2	3:5		3:4		1:1	6:5	5:4	5:2
3:10		2:5		1:2	3:5		4:5		1:1	2:1
1:4		1:3			1:2		2:3		5:6	5:3
				1:3	2:5				2:3	4:3
		1:4			3:8		1:2		5:8	5:4

Ratio

The calibrated focal length of the taking camera is set on both plotter cameras. The picture carriers are removed and the diapositives are placed emulsion side down on their respective carriers, on which they are carefully centred by bringing the collimating marks into exact coincidence with the marks engraved on the picture carriers. This centring is done on a specially manufactured light box, and under magnification. The picture carriers are now carefully replaced in their respective camera frames and with their common overlap correctly oriented towards the central Φ-axis. For more exacting work, correction plates are mounted in the picture carriers in place of the ordinary glass plates.

A negative may be used instead of the diapositive; but in this case the negative is mounted emulsion side upwards, and is held flat with a glass covering plate.

Outer orientation is concerned with setting up a space-rod model, correctly oriented within itself and with the plotting table, and at the scale required by the combination of map scale and gear-ratio.

Relative orientation may be carried out by systematically removing K at six suitably placed points (Fig. 11.6) in much the same way as with the multiplex. The manufacturers do suggest a particular procedure, but warn that it was actually designed for use with photographs of flat terrain. It differs only in detail from the drill described for the multiplex.

With reference to Fig 11.6, K is removed

at point 1 by swing of photo 2
at point 2 by swing of photo 1
at point 5 by tilt of photo 1
at point 3 half by tilt of photo 1, and half by tip of photo 2
at point 6 by tilt of photo 1
at point 4 half by tilt of photo 1, and half by tip of photo 1
at point 6 (or 1) by tilt of photo 1
at point 2 (or 3) overcorrect n-times by tilt of photo 1

Repeat all steps until the model is free from K.

In fairly flat country an approximate value for the overcorrection factor would be

$$n = f^2/a^2$$

where a = image ordinate of point 2 (or 3).

In cases where several repetitions of this drill do not result in reducing K, then more sophisticated calculations for determining the overcorrection factor are called for, though a suitable value for n may be found fairly easily by trial and error.

Absolute Orientation

We shall assume for the moment that we wish to plot the detail from a single overlap on to a base-grid on which adequate control is available, say as in Fig. 11.7, where *A* and *C* are also horizontal control points.

Scaling. The base-grid is placed on the plotting table and oriented so that the pencil positions representing two well-separated control points (say *A* and *C* in Fig 11.7) lie along the line joining the plotted positions of these points. The correct scale of the instrument model is obtained by adjusting the base-length, S_1S_2, until the length of the plotted line *AC* equals its length on the base-grid. The corrected length of S_1S_2 can be calculated by proportion in the same way as for the multiplex.

Horizontalizing. This is simpler than as described for the multiplex, as the whole superstructure may be rotated about the central Φ-axis. If a pair of height control points are located on the photographs at nearly equal distances on either side of the right-bisector of the base-line (*A* and *F* on Fig. 11.7), then the glass scale should be set to give the correct height-index reading at say the left-hand point, and the height error at the other point should be eliminated half by adjusting the glass scale and half by using the Φ-rotation and the *X*-, *Y*- and *Z*-scanning movements. This drill may need repeating until no error remains. If necessary the height error at one of the two points, say at *F*, may be estimated in the same way as it was for the multiplex; i.e. by interpolation between the errors at *C* and *B* and then by extrapolation.

The same procedure may be followed for an Ω-orientation, using simultaneous and equal ω_1- and ω_2-movements to adjust between a pair of height-control points placed symmetrically about the Ω-axis.

Finally the scale is checked and the glass scale is again adjusted to give the correct height-index readings, and plotting can begin.

Aerotriangulation with the A8

The A8 is not designed for bridging; but this can be achieved with a cross-level, which is an inclinometer similar to that used with the multiplex. After the first model has been fully oriented, the cross-level is fixed to the right-hand picture carrier, and the inclination measured in two perpendicular directions. The first diapositive is now removed. The second diapositive in its picture carrier and with the cross-level still attached, is placed in the left-hand camera. The diapositive of photo 3 is now mounted on another picture carrier and inserted in the right-hand camera. Relative orientation is carried out, and photo 2 (now on the left-hand camera) is given the same orientation as before by bringing the two cross-level bubbles to the centres of their runs with ω_1- and Φ-movements. Eliminate K with ω_2 and carry out the scaling adjustment between two points already plotted from the previous model, i.e. between two points in the double overlap. Similarly at a previously heighted point (again in the double overlap) set the heighting scale so that it reads correctly. Both the horizontal scale and height-index readings should be checked against other points from the previous model.

Another cross-level is attached to the photo-carrier holding photo 3 and the bubbles are brought to the centres of their runs. Photo 3, again with photo carrier and cross-level attached, is removed to the left-hand camera and the third overlap is oriented in the same way as was the second.

A complete bridging operation can be carried out in this way, and adjustment to the bridge may be completed using techniques similar to those used for the multiplex; but in practice it will normally be performed by analogue or digital computer. The latter techniques are almost wholly automatic, since the coordinates of points are automatically recorded in print and on punched tape by linking the A8 with an electric coordinate printer and a tape punch machine. The tape is then fed into a computer, previously programmed to carry out the whole computation and fed with appropriate control information. The result will be sufficient control to enable each overlap in turn to be set up in the machine for plotting.

The manufacturers hope that an ortho-photo attachment for standard A8s will be available in 1972.

The A7 Autograph

The A7 and A8 have basically similar carriage complexes, together with similar rotational movement of the cameras; but in some fundamental respects there are important differences. The A7 is more rigid and massive than the A8, the base distance (b in Fig. 12.13) is not adjustable, and there is no common Φ-movement in the A7. However, the A7 rods are attached to the Z-carriage in such a way that there are separate translatory adjustments in b_y and b_z for each rod (see Fig. 12.13), which has the effect of altering the relative positions of S_1 and S_2 in the Y- and Z-directions, i.e. altering the bearing and inclination of the air-base in the space-rod model. The effective distance between S_1 and S_2, and therefore the scale of the model, is adjustable by a joint b_x-movement of the lower ends of the rods relative to the Z-carriage.

The upper end of an A7 space-rod moves the viewing telescope over the face of the diapositive in such a way that the telescope is not only always perpendicular to the face of the diapositive but also vertically above the end of the space-rod. Thus when the space rods are vertical the respective principal points are being viewed, so that when the overlap portion of the photos is between the two

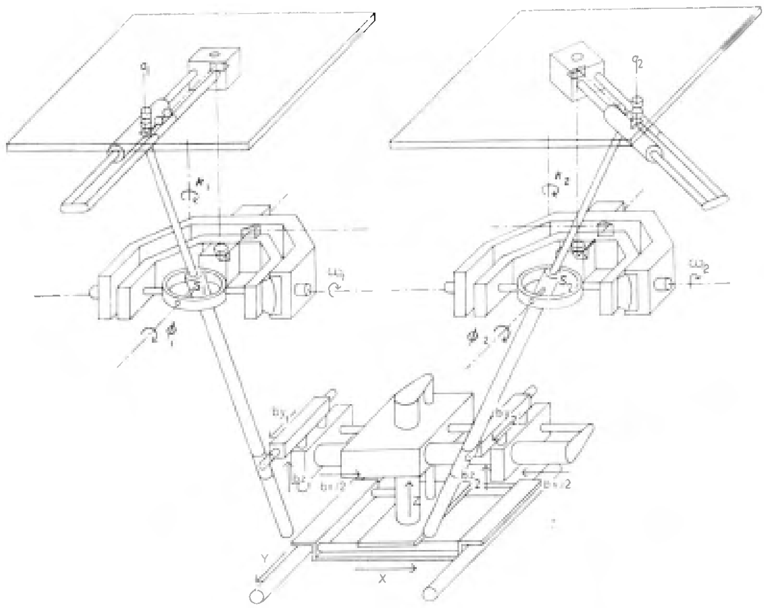

FIG. 12.13. WILD A7 AUTOGRAPH SPACE-ROD DIAGRAM
(*Wild, Heerbrugg Ltd.*)

principal points (i.e. in the normal position), the upper ends of the rods will be closer together than the lower ends. The point of intersection of the lines of the space-rods would then be above the plane of the diapositives, and as the parallax decreases so the lower ends of the rods approach one another and the Z-carriage falls—there is therefore no need for the rod motions to be reversed by lazy-tongs as with the A8.

The A7 is a more expensive instrument than the A8; but the essential difference is that the A7 is specifically designed for aero-triangulation as well as for plotting. Besides the ability to simulate a

B_y-movement of each perspective centre, it is possible to switch the viewing system so that the image of the right-hand picture is brought to the left eye, and the image of the left-hand photo to the right eye. This cross-over position of the viewed images is known as the base-out position because it is the outside part of the diapositives which are being viewed. The normal position is then referred to as base-in. Thus the first two diapositives are mounted with the instrument in the base-in position, photo 1 in the left-hand camera and photo 2 in the right. Relative orientation similar to that for the A8 is completed, photo 1 is replaced by photo 3, and the optical train is switched to its base-out position. The orientation of photo 2 is not altered in any way; but the left-hand camera, holding photo 3, is oriented relative to photo 2 in a way similar to that used for 7-projector multiplex bridging, the b_y- and b_z-movements of the foot of the left-hand space-rod relative to the carriage system being used to simulate B_y- and B_z-movements of the left-hand perspective centre. In effect this enables the left-hand photo base-line to be made collinear with the right-hand base-line, and for the correct inclination of the air-base to be set in the space-rod model.

The A8 is incapable of any differential Y-movement between the two cameras, so that the fact that on photo 2 the base-line of the second overlap is most unlikely to be collinear with the base-line of the first overlap (see Fig. 5.4) presents a problem which could only be solved by a rotational movement about the plumb line; but the swing rotation is, of course, about the principal axis of the camera. We have just seen that the b_y-movements of the rods relative to the Z-carriage enable the A7 to overcome this difficulty.

The manufacturers state that the A7 is designed to perform the following tasks—

1. Preparation of large-scale plans between 1/500 and 1/2,500 for technical projects, cadastral purposes, reallotment schemes, and town surveys.
2. Photogrammetric preparation of numerical cadastral surveys.
3. Photogrammetric measurement of profiles and cross-sections for planning railways and highways.
4. Increasing the density of the ground control network by bridging at large scales for providing coordinated points for map revision, instead of fixing such points by lower-order triangulation and traversing.
5. Photogrammetric determination of positional coordinates and elevations for medium and small scales by the method of aerial triangulation.

6. Preparing large-scale contour plans from small photograph scales for preliminary technical investigations.

7. Preparing maps at all medium and small scales when no simpler plotting instruments are available.

8. Plotting from terrestrial photo-theodolite photographs.

9. Of much lesser importance: plotting from less-frequently encountered types of photography such as obliques and convergent photography; and aerial triangulation from convergent photographs with large convergent angles.

This is the picture of a fully versatile instrument, truly universal by any criterion.

The A8 can be used for all items from 1 to 7. It would normally be used for item 7 and probably also for 3 and for much of 1.

The picture carriers with cross-levels attached are interchangeable between the A7 and A8, and one of the more important tasks of the A7 is to feed a group of three or four A8s with control and oriented picture carriers, so that the A8s may be used for plotting detail, the purpose for which they were mainly intended. Auxiliary equipment, such as the plotting tables, profiloscope, the electronic co-ordinate printer and the card punch and tape punch machines can be used with either the A7 or the A8. It is estimated that for plotting at medium scales, one A7 and four A8s are able to produce twice as much work in a given time as could three A7s alone. This serves to underline the need for a range of instruments, in that, however many tasks a particular machine *can* perform, it is most economically employed for its own specialization.

The B8 Aviograph

The B8 is a smaller and simpler instrument than either the A7 or the A8, but it still maintains a rigorous geometrical solution of the space model. Fig. 12.14 shows the space-rods in diagrammatic form. It will be seen that the perspective centres are above the universal joints which control the movements of the viewing telescopes, so that the space-rod arrangement directly simulates the perspective rays (cf. Fig. 6.2). The instrument is basically intended for map revision and plotting at medium scales from wide-angle and ultra-wide-angle photography; but it can also be used for large and small scales.

Each camera is supported by an interchangeable camera carrier, which sets the focal length. Camera carriers are available with five different focal lengths: 152, 125, 115, 100, and 88·5 mm, and each is fitted with a micrometer adjustment which can vary the focal length by up to 3 mm either way. Note that on the A7 and A8 the focal length is continuously adjustable over a considerable range.

Plotting may be done on the supporting table top, in a manner similar to that of the multiplex; but it is possible to plot on a separate plotting table, in a way reminiscent of the Autographs, but using a linear pantograph instead of a coordinatograph.

By reason of its relative simplicity of construction and operation, and the rigorous solution, the B8 is particularly suitable for photogrammetric investigation for engineering and scientific purposes. An expert in a particular science can use the B8 without a long period of training, which would be necessary for a more complex instrument—this gives him direct access to a rigorously correct model of the land or object under investigation.

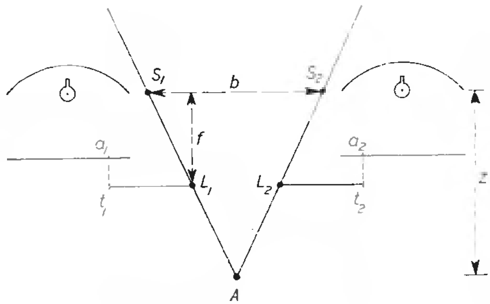

FIG. 12.14. WILD B 8 AVIOGRAPH SPACE-ROD DIAGRAM

The A9 Autograph and The B9 Aviograph

The A9 (Fig. 12.5) and B9 are designed for use with photography taken by the Wild RC9 super-wide-angle camera, but they will also accept wide-angle photography. Both use diapositives reduced to half the size of the negative. Because of the reduction in the number of photographs and the consequent saving in flying time and more especially the saving in ground control, super-wide-angle photography is normally preferred for small-scale mapping projects—that is, for scales of 1/50,000 or less.

Instruments designed for limited ranges of work can be simpler than the more universal machines, and they will therefore be less costly, quicker to orient and usually easier to operate. The A9 is universal in the sense that it is intended for aerotriangulation. It is very similar to the A7, but is simpler and smaller. The B9 is a smaller version of the B8, but is designed to plot the detail from the diapositives previously triangulated on the A9. Special diapositive printers are required for use with these instruments. Besides making the required reduction in scale, the printers incorporate a correction for lens distortion of the camera being used and, where needed, a further correction for earth curvature and mean atmospheric refraction according to the flying height.

The A10 Autograph

Change is continuous, and the B9 is being discontinued, whilst the latest addition to the Wild range is the A10 (Fig. 12.6), which is described as being intermediate between the A7 and the A8. The A10 is suitable for aerotriangulation, coordinate recording, and for plotting vertical photographs having angular views of up to 120°. By an interchange of the drives to the *Y*- and *Z*-carriages, it is also capable of plotting from terrestrial photographs.

It is recommended that the A10 and B8 should be used in harness, just as the A7 and A8 are paired; thus for the highest precision, largest scales and closest contour intervals the A7 will triangulate and the A8 will plot, while for the less demanding work the A10 will triangulate and the B8 will plot the detail. It is in fact anticipated that the B8 will overtake the A8 as the most popular instrument.

The A40 Autograph

The A40 (Fig. 12.15) is designed for plotting from pairs of terrestrial photographs, taken with either specially designed stereo-cameras, or from pairs of photo-theodolite pictures. This is sometimes known as close-range or short-range photogrammetry. Photographs taken with specially designed stereo-cameras are known as fixed-base or short-base photographs. Some uses to which such photography may be put are mentioned in the next chapter.

Wild have produced the P30 photo-theodolite, with a 165 mm focal length and 100 mm × 150 mm format. This is being replaced by the P31, a completely new design, which will probably be available in 1972. In addition the company are producing the P32, which is a camera designed for attachment to any standard Wild T2 theodolite. The P32 will have a 65 mm × 90 mm plate format and a focal length of about 64 mm; it will also be possible to use this camera without the theodolite.

Wild also produce a range of three stereometric cameras: the C120 and C40 each consist of a pair of wide-angle cameras separated by a stable rigid bar or base, mounted on a tripod, the base-lengths being respectively 1·2 m and 0·4 m; the C12 has normal-angle cameras with a 1·2 m base. These cameras are capable of taking certain inclined shots as well as horizontal photography.

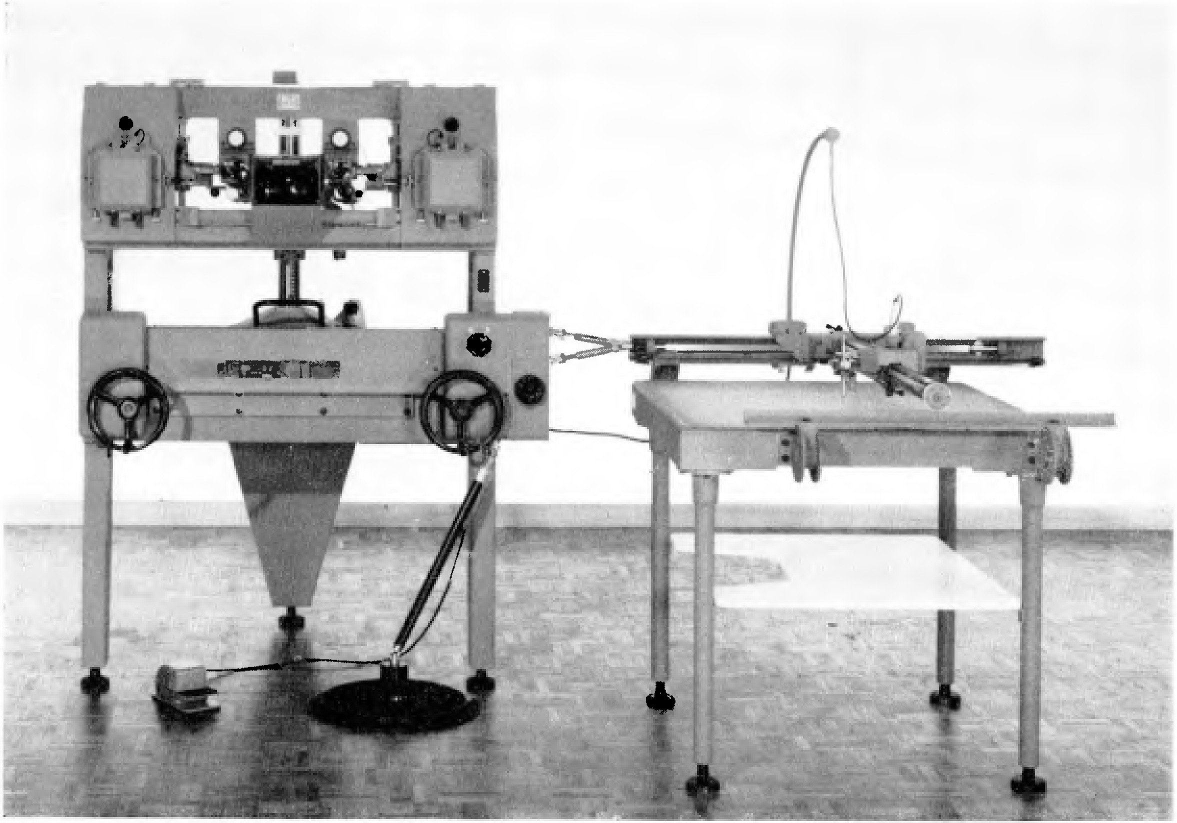

Fig. 12.15. The A40 Autograph
(*Wild Heerbrugg Ltd.*)

The RC7a, RC8, RC9, and RC10 Air Cameras

There is a range of four Wild air cameras likely to be encountered in current commercial use.

The RC7a, successor to the RC7, is a plate camera with 140 mm × 140 mm format and has two interchangeable lenses—a normal-angle and a wide-angle lens, with 170 mm and 100 mm focal lengths respectively. Fig. 4.10 shows the RC7 and Fig. 9.20 shows the way in which the plates are stored in the magazine and fed into the exposure position. Plate photographs are especially suitable for producing enlarged prints for mosaic making.

The RC8 is a film camera with vacuum-frame type of film-flattening device, and intended for wide-angle photography with a 152 mm focal length lens and a 230 mm × 230 mm format. The photographs are suitable for plotting in any of the Wild instruments described above (except the A40), and most other major instruments.

When fitted with the Wild Universal-Aviogon *f*/5·6 wide-angle lens cone, and the appropriate filters, the RC8 can be used with panchromatic, infra-red, colour, or infra-red colour film. The magazine holds 60 m of film having an overall width of 240 mm. The viewfinder is of the type illustrated in Fig. 4.9 (upper photo). It has been estimated that wide-angle cameras with 152 mm focal lengths account for 80 to 85 per cent of all vertical air photography, and Wild believe the RC8 to be the most popular camera in the world.

The RC9 is a specialist film camera, designed for super-wide-angle photography for making small- and medium-scale maps and for aerotriangulation in the A9, or A10. It has an *f*/5·6 Super-Aviogon lens, with a focal length of 88·5 mm (format 230 mm × 230 mm). Very little air photography is done with cameras with lenses of focal length other than 152 mm or 88·5 mm.

The RC10 (Fig. 1.7) is the latest Wild air camera. It is a film camera incorporating new design elements and is intended to supersede both the RC8 and RC9, which are already out of production (March 1971). This camera has a 230 mm × 230 mm format, but is more compact than its predecessors, and has interchangeable lenses—one wide-angle with 152 mm focal length and one super-wide-angle with 88·5 mm focal length. A narrow-angle, 305 mm focal length lens is expected to be added later.

In addition to cameras and plotting instruments Wild produce almost all items of photogrammetric equipment and accessories, including: a camera mount, horizon camera, registering statoscope, stereocomparator, enlarger, rectifier (or rectifier-enlarger), a range of diapositive printers, processing equipment (Figs. 9.2 and 9.4), various stereoscopes and a point-transfer device. The PUG3 and PUG4 point-transfer-device instruments are designed for easy stereoscopic transfer of image points from one photograph to another, and for marking them. Points can even be transferred between photographs of different scales.

THE CHOICE OF INSTRUMENTS

Classification according to "order", degree of precision and C-factor only takes into consideration a limited range of characteristics. Another perhaps broader classification might be as follows—

1. Universal and precise—e.g. A7, Stereoplanigraph, Photostereograph
2. Precise and designed for aerotriangualtion—e.g. A9
3. Precise plotters—e.g. A8
4. Exact solution but lower precision—e.g. B8, PG2
5. Anaglyphic instruments—e.g. multiplex, Balplex
6. Approximate solution instruments:
   (*a*) so-called 3rd order—e.g. Stereomicrometer, Stereotope
   (*b*) sketching only—e.g. Sketchmaster, Radial-line plotter

This would be some help in discussing the attributes of instruments; but in making a practical choice, it would be necessary to pose certain questions, and it seems appropriate to conclude this chapter with a suggestion as to what some of these would be. It is assumed that we would be using vertical black and white photography.

Each instrument possesses certain attributes which help to determine its suitability for any particular purpose. Perhaps the most important of these are—

1. The order of the work for which the instrument is intended (first, second, third order or only sketching or minor revision).
2. Position accuracy of which it is capable.
3. The ratio between flying height and heighting accuracy—the *C*-factor takes care of this.
4. The range of plotting scale to photo-scale ratio, including the *z*-scale range (i.e. projector to floating mark distance on the multiplex).
5. The quality of the stereoscopic model and ease of operation.
6. Average time required for orientation.

In choosing an instrument for a particular project, the following factors are important—

(*a*) What is the purpose of the survey? Is a plan, relief, or numerical information required?
(*b*) Scale of the plot required relative to the scale of photography.

(*c*) Position accuracy required and amount of control available.
(*d*) Heighting or contouring accuracy required, and amount of height control available.
(*e*) The quality of photography, including B/H ratio.
(*f*) The availability of machines.

FURTHER READING

(i) Schwidefsky, pages 205–52.
(ii) Moffitt, pages 360–96.
(iii) *Manual of Photogrammetry*, Vol. II, Chapters 14 and 15.

CONVERGENT PHOTOGRAMMETRY

(i) Moffitt, pages 439–45.

(See Bibliography (page 346) for full titles.)