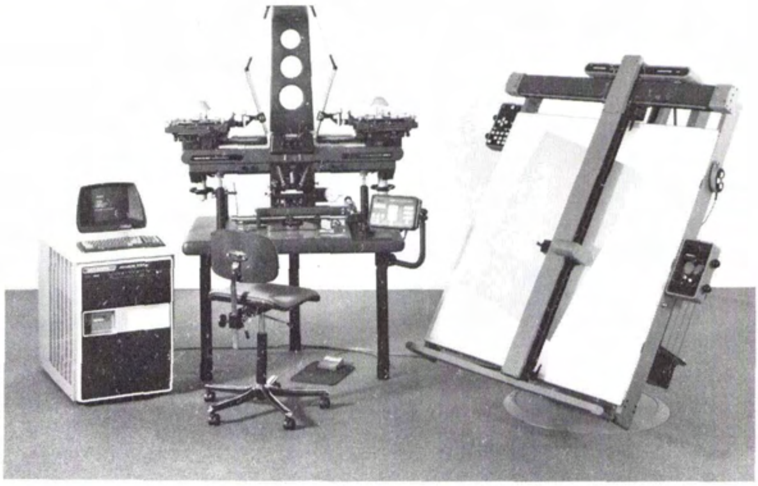

FRONTISPIECE. The Wild Avioplot RAP System with the Wild Aviograph AG 1 stereoplotter.

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# New Instrumentation for Direct Photogrammetric Mapping

## The Avioplot RAP System employs an interactive alphanumeric display and minicomputer to tie an analog stereoplotter to the Aviotab TA digital plotting table.

*(Abstract on next page)*

### INTRODUCTION

DIRECT GRAPHICAL PLOTTING is still the main task of any photogrammetry office or organization. To date, horizontal mechanical plotting tables have been used, attached to the plotting instrument. The operator or an assistant had to rework the drawing produced by mechanical means and to complete this on the plotting table. The cartographer then had to produce a final copy from such reworked manuscripts. This process can now be automated and improved with the aid of computers and inclined digital plotting tables. This paper describes the new automation equipment for autographs, Wild Avioplot RAP, which makes possible substantial savings in time in large scale mapping of residential areas, railway stations, front sides of buildings, and in plotting spot heights in flat terrain. In addition, plotting (e.g., on engraving foil) is of high quality. The flexibility of the system allows it to be adapted to a great extent to the wide variety of requirements for plans and maps with regard to draftsmanship, i.e., symbols used, line thicknesses and patterns, lettering, etc. The plot which can be obtained in the plotting instrument thus approximates very closely the finished product and can in many cases be sold as such. At the very least, further work is greatly facilitated (field comparisons, planning, fair copy). The operator's work is made much more straightforward.

### SYSTEM COMPONENTS

The Avioplot RAP can be connected to any photogrammetric plotting instrument. It replaces



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ABSTRACT: *A new range of opportunities opens for direct mapping in photogrammetry as a result of inexpensive process computers and digital plotting tables. With these new aids, maps can be produced more quickly, more conveniently, and in a more definite form. The Avioplot RAP System by Wild Heerbrugg is this kind of automation equipment for the Aviotab TA digital plotting table and any type of analog plotting instrument. The components of this system and its performance are described.*

the mechanical plotting table such as the coordinatograph or pantograph plotting table. The Frontispiece shows the Avioplot RAP with the new Wild Aviograph AG 1 stereoplotter. The following components form part of the system (Figure 1):

- digital plotting table Aviotab TA,
- Data-Acquisition- and Control-Computer PRI 1,
- Functions Keyboard PFKB 1, and
- process computer with mass storage device and alphanumerical monitor screen terminal.

These components are controlled and supervised by complex programs in the computer. The operator uses the system interactively by means of the keyboard and footswitches. He receives instructions on the screen and checks his data. In the event of faulty manipulations on his part, acoustic signals are given or appropriate indications are displayed on the screen. In the design of the Avioplot RAP, the aim has been to achieve an ideal division of computing between the main computer and the peripheral computers inside the keyboard and the table. This results in a high measure of adaptability, convenience, and reliability. A detailed description of the components follows.

#### DIGITAL PLOTTING TABLE AVIOTAB TA

This plotting table has been in production since 1977, and large numbers are already in service (for detailed descriptions, see Frey (1976) and Höhle (1978) ). A number of modifications and improvements have been made to the Aviotab TA since production began. These concern, in particular, the quality of the drawing and the plotting tools. Good quality plots on engraving material are now possible. In connection with the RAP automation equipment, attention is drawn to the following characteristics:

- Usable plotting area — 1200 mm by 1000 mm
- Absolute accuracy for plotted and digitized points — 0.1 mm
- Relative tracking accuracy (line quality) — 0.05 mm
- Maximum speed in axial direction — 125 mm/sec
- Maximum acceleration in axial direction — 700 mm/sec²

The plotting surface can be tilted to an angle of 90$^g$ and may be equipped with an adjustable transmitted-light unit. A control box enables the table to be manually controlled.

#### DATA ACQUISITION AND CONTROL COMPUTER PRI 1

The PRI 1 data acquisition and control computer is inserted in the electronics unit of the Aviotab TA. It consists of two printed-circuit boards which contain a microprocessor based on the Intel 8085. The PRI 1 has been described in detail by Höhle (1979) and has been in practical use since the beginning of 1979 in a number of installations. Its function is to relieve the main computer, particularly for the control of the table. It deals with

- controlled starting and stopping of the plotting head, and
- execution of repetitive and time-critical computations such as straight-line interpolation and generation of lettering, etc.

Further, the *XYZ* coordinates of the stereoplotting instrument are acquired and transmitted to the main computer or table. The table coordinates, *x*, *y*, can also be acquired. The PRI 1 is connected with the main computer by means of a serial interface (RS 232C). The data are transferred between the two computers at a speed of 9600 baud. The maximum plotting speed can be reduced, thus achieving an improved plotting quality with certain of the plotting tools.

#### FUNCTIONS KEYBOARD

The Functions Keyboard PFKB 1 (Figure 2) is placed adjacent to the photogrammetric instrument and the operator. It has a clear arrangement of keys for frequently required plotting operations and a keyboard for entering numerical data. The double footswitch of the Aviotab TA is connected with the PFKB 1. This footswitch acts as two external function keys. The keyboard is connected with the main computer via a serial interface (RS 232C), and information is transmitted in both directions. The Functions Keyboard contains a microcomputer (Intel 8748) and an acoustic signaling device. The keys are luminous and there is

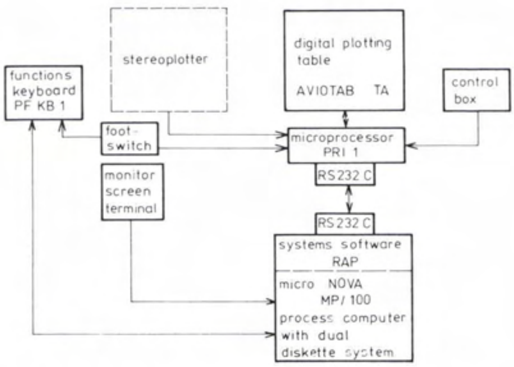


FIG. 1. Components of the Avioplot RAP

a four-figure alphanumeric display. Thus, in conjunction with the computer, faulty manipulations are signaled acoustically, and keys pushed are lit, selected data such as the type of symbol and line, speed, and status of the pen are made visible as letters or figures on the display. The alphanumeric monitor screen also operates in conjunction with the Functions Keyboard. By pressing certain keys on the Functions Keyboard, tables appear on the monitor screen, in which various parameters (e.g., size of characters, text, etc.) can be altered as required. The Avioplot RAP is operated almost entirely from the Functions Keyboard and the footswitches. The keys can practically be operated blind, i.e., observation of the stereomodel need be interrupted only infrequently.

### THE PROCESS COMPUTER AND PERIPHERALS

The process computer of the Avioplot RAP is a standard Data General micro Nova MP/100. This compact 16-bit minicomputer is equipped with a 64 K-byte memory. Further 630 K-byte memories are provided by a dual diskette system. The programs have been written in FORTRAN and are stored on two replaceable diskettes in object code.

The computer and its operating system possess the requisite characteristics for use with the Avioplot RAP, such as

- the simultaneous execution of several programs (MULTITASKING) and control of their sequence according to predetermined priorities,
- the ability to break long programs into segments by using external diskette storage ('OVERLAY' technique), and
- an adequate speed

For input and output, the Data General Dasher D100 monitor-screen terminal is available. Screen and keyboard are separate from each other, and both can be placed on the computer itself or on a special trolley. The screen can be rotated and tilted. The characters displayed are shown with good contrast and resolution, and, to prevent dazzle, the screen is slightly recessed. Figures may also be entered from a separate part of the keyboard.

## SYSTEMS PROGRAMS

The systems programs comprise six principal programs. These can be selected by the user by calling up the appropriate line (Figure 3).

For plotting as such, only program 5 (COMPILATION) is required. This is far and away the most comprehensive program and operates together with the Functions Keyboard. The other programs are used for preparatory work. They are required only occasionally. The following provides, first, a general view of the functions of the sub-programs. The program package for computer-aided plotting is then treated in rather more detail. Finally, a number of programming details and features of the systems programs are explained. Some examples will demonstrate the abilities of the system.

### GENERAL DESCRIPTION OF PROGRAMS

*Data input.* The program is used for the input of data and constants, i.e.,

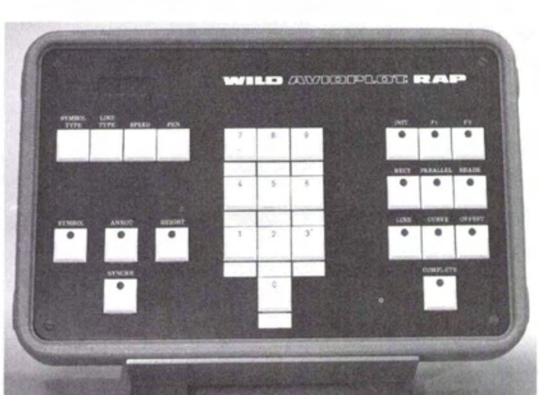


FIG. 2. Functions keyboard of the Avioplot RAP

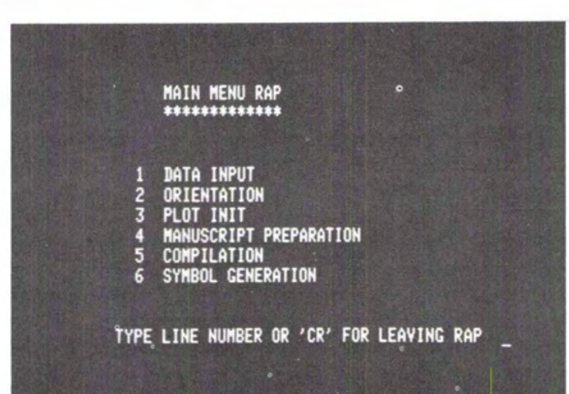


FIG. 3. Principal programs of the Avioplot RAP

- control points,
- characteristics of the photogrammetric instrument, and
- project data

In general, a photogrammetric project is started with this program. For a second model, this program can be skipped.

*Orientation.* This program is used for the absolute orientation of the stereomodel. First, the model coordinates of the control points are measured one after another. The program searches for the corresponding ground control points, which are stored on the diskettes for a whole project. The solution is found in a least-squares adjustment. Residuals at the control points are displayed in model units (mm) or in ground units (m or ft). If no editing or repeat of the measurement is necessary, the computed values of orientation are then set on the stereoplotter.

*Plot initialization.* This program takes care of the allocation of symbols from a stored library to ten keys of the Functions Keyboard, the determination of line types and their allocation to the ten keys, and the determination of the form in which the coordinates will be displayed on the screen. In general, this preparatory work needs to be carried out once only for any given object. Thus, this program will need to be called up only occasionally.

*Manuscript preparation.* This program covers

- the plotting of a grid,
- the plotting of control points, and
- the plotting of text.

*Computer-aided mapping.* This is the main program. When this is called up, the Functions Keyboard is also made operational. In part, the keys control certain measuring programs which must then be precisely followed. The requisite instructions appear on the screen. For parameter changes that may be required (e.g., size of characters for text, etc) tables are displayed simultaneously on the screen if certain keys are pressed, and the parameters applicable at the time are also displayed.

*Symbol generation.* With this program, almost any symbol can be generated by the user and stored. For this purpose, the required symbol is drawn by hand to a larger scale and is then digitized at the plotting table. It can be plotted for test purposes, and the same applies to the entire contents of the symbol library. Up to 999 symbols can be stored.

## COMPUTER-AIDED MAPPING

This program is executed in conjunction with the Functions Keyboard (Figure 2). The most important functions are explained below:

*Plotting individual symbols (SYMBOL).* This key is used for plotting individual symbols (point symbols, area symbols). After pressing it, the required symbol has to be selected. There are two possibilities:

- The symbol is already available in the computer and allocated to one of the ten keys (The size of the symbol and its angle are thus already determined). In this case, the 'symbol type' key needs also to be pressed, followed by the 'figure key' marked with the required symbol.
- The 0 key can be used on a short-term basis to select a single symbol (including its size and angle). On the screen, the relevant questions appear and the operator enters the type of symbol and parameter required on the monitor-screen keyboard.

Once the symbol has been determined by one of these two methods, it can be released by means of the footswitch. Subsequently, the same symbol can be plotted without the need to wait for it to be completed on the plotting table. The required positions are stored in the computer memory. The selected symbol is always shown in the display. The code numbers of the available symbols are given in a table which can be plotted out (symbol library, Figure 4).

*Lettering (ANNOTATION)* The plotting of text can be carried out in the course of a photogrammetric plot by pressing the 'annotation' key. A table of choices then appears on the screen, in which the size and angle of the lettering can be specified. In addition, the text to be plotted can also be entered. An annotation is always released by means of the footswitch. The angle of the characters can also be derived from measurement.

*Plotting of spot heights (HEIGHT).* The height set in the stereoplotter can be plotted automatically. For this purpose, the HEIGHT preselector key is used. The parameters for plotting spot heights can again be selected from a table of choices. After the HEIGHT key has been pressed, the table shown in Figure 5 appears on the screen. This function is carried out by pressing the footswitch. The symbol is plotted first. Then, with a free choice of position, the number is marked on the plot when the footswitch is pressed a second time. As a result, the position of a height number can be freely selected.

*Displacement from an existing position (OFFSET).* If it is desired to move the plotting head from its present position, the OFFSET key is pressed. The direction of travel and its distance can previously be specified during initialization. The plotting head returns to its original position by pressing any key.

*Straight-line plotting (LINE).* If two points need to be connected by a straight line, the LINE key is pressed. If then the footswitch is pressed, the point set is stored in the computer. The plotting head remains on this point until the footswitch is

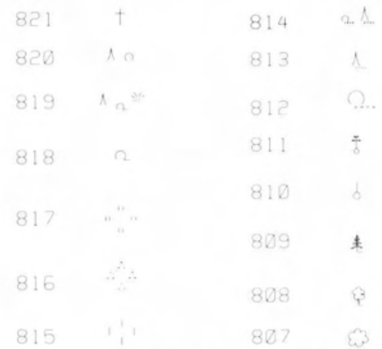


FIG. 4. Extract from a symbol library

| Line type | Example | Specifiable parameters |
| --- | --- | --- |
| Solid | ——— | — |
| dashed (broken) | – – – – | length of dash |
| dot-dashed | —·—·— | length of dash, number of dots |
| solid with single symbol | v v v v | code and size of symbol |
| dashed with single symbol | —+—+ | distance between two symbols |
| arched | ⌒⌒⌒⌒ | radius of arc |

FIG. 6. Line types of the RAP System.

pressed again. It then plots a straight line to the new point. The type of line must have been previously selected (LINETYPE key and keys 0-9); the types shown in Figure 6 are available for this. If the left footswitch is pressed, the pen is raised and the head follows the movements of the operator. If the lines are perpendicular to each other (e.g., in the case of buildings), the RECT key can be pressed. The second line will then be plotted at a perfect right angle to the first. If the right angle is set, the last two sides of a rectangle can also be completed automatically. Figure 7 shows the 'blind' measuring procedure for plotting buildings.

*Plotting curves lines (CURVE).* If curved lines need to be plotted, the CURVE key is used. First, the first and second points of the curve are recorded (right-side footswitch). After the third point has been recorded, points 1 and 2 are connected by the curve, i.e., the plotting head is always one point behind. The curved line is completed only after the left-side footswitch (TERMINATE) has been pressed. The individual points must be set in such a way that no maxima or points of inversion lie between them.

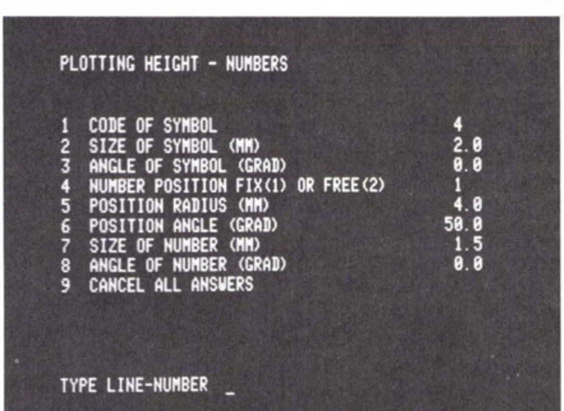


FIG. 5. Menu for plotting height numbers.

*Plotting parallel lines (PARALLEL).* In plotting topographic features such as roads, footpaths, railways, retaining walls, etc., the second line can be automatically plotted parallel to the first. The measuring program is so designed that, after recording the first point of the 'reference line,' one point of the parallel line has to be recorded (in order to establish the distance between them).

*Shading of areas (SHADE).* Closed polygons or areas formed by curved lines can be shaded. In addition to the LINE or CURVE keys, the SHADE key is pressed. After releasing the COMPLETE key at the last point, the plot is completed to the starting point and thereafter the area enclosed is shaded. The spacing of the shading lines and their angle can be determined in the initializing procedure (INIT).

### VARIOUS PROGRAMMING DETAILS

The FORTRAN programs of the Avioplot RAP are stored in object code on two replaceable diskettes. On account of the high-performance DOS operating system and the use of FORTRAN as the language, the programs require little time for their execution.

The principal programs have a number of features that call for comment. The manual entry in the two keyboards and the communication with the PRI 1 Data-Acquisition- and Control-Computer are operated by separate and individual tasks (small programs). These tasks are permanently stored in the computer. It is thus possible, during a plot, to press function keys and to alter parameters at the monitor-screen terminal. Similarly, there is a 400-word circular buffer perma-

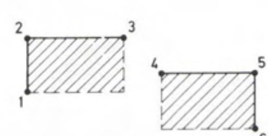


FIG. 7. Measuring procedure for the mapping of buildings


FIG. 8. Direct plot of a 1:1000 site plan. The line types and symbols are those required by a private firm in Germany, derived at short notice by the operator. The shading and the spot heights were plotted automatically. Mapping was completed in about a third of the time that would have been normally required (compared with a plot produced without computer system or digital plotting table).

nently in the computer memory. In this relatively large buffer, the measurements made by the operator and the output instructions to the plotting table are picked up. Thus, the operator can continue his measurements unhindered and also change parameters. The plotting table produces the plot in parallel and in correct sequence. Some parts of the program are stored on the diskettes as overlays. These are loaded into the computer memory as required, practically without loss of time. On the diskettes, there are also files for the monitor-screen text, the symbol library, and control points. These are read into the computer memory as required and are later again deposited on the diskettes. When the computer is switched off, the parameters last used are saved for later re-use.

Program parameters are changed by answering questions displayed on the monitor screen. These are arranged in tables (so-called menus), and a response is required only with regard to the line to be changed. Instructions for measuring procedures similarly appear on the monitor screen.

## SOME APPLICATIONS

There is a wide range of applications possible for the Avioplot RAP. Its main advantages are in large-scale mapping where there is a large number of artificial objects to be plotted, such as buildings, walls, roads, railways, etc. Similarly, plans containing many spot heights or much text can also be produced advantageously. Further, there are cases where pairs of stereophotographs call for a relatively great expenditure of time for unproductive preparatory work (orientation and mapping of control points) compared with that required for plotting. This is particularly the case in revision of existing maps. Figures 8 and 9 show a few applications. They are in each case original plots made directly on engraving foil. For reasons of space, they have all been reduced to about half their

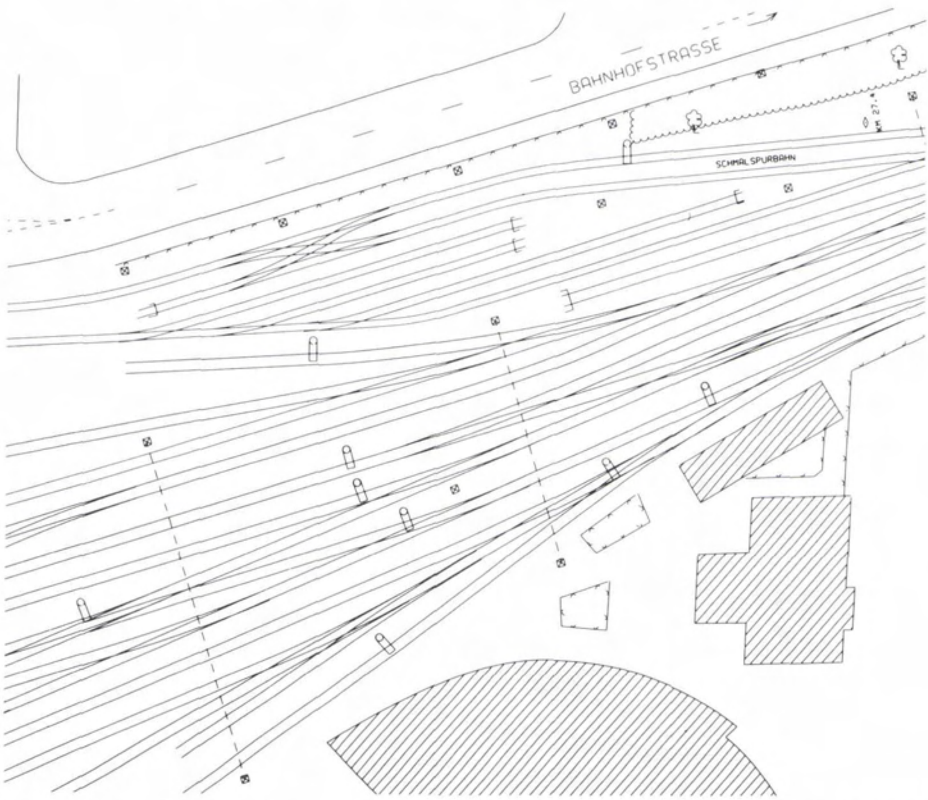


FIG. 9. Direct plot of a railway station at a scale of 1:500. One of the two lines of each of the tracks was digitized by means of a small number of points, and the other was mapped automatically. The symbols for the signals, kilometer-stones, masts, and lettering are oriented in a predetermined direction.

original size. They have not been retouched or reworked in any way.

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## Forthcoming Articles

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*R. Welch*, *P. N. Slater*, *H. Tiziani*, and *J. C. Trinder*, ISP Image Quality Working Group Activities, 1976-1980.