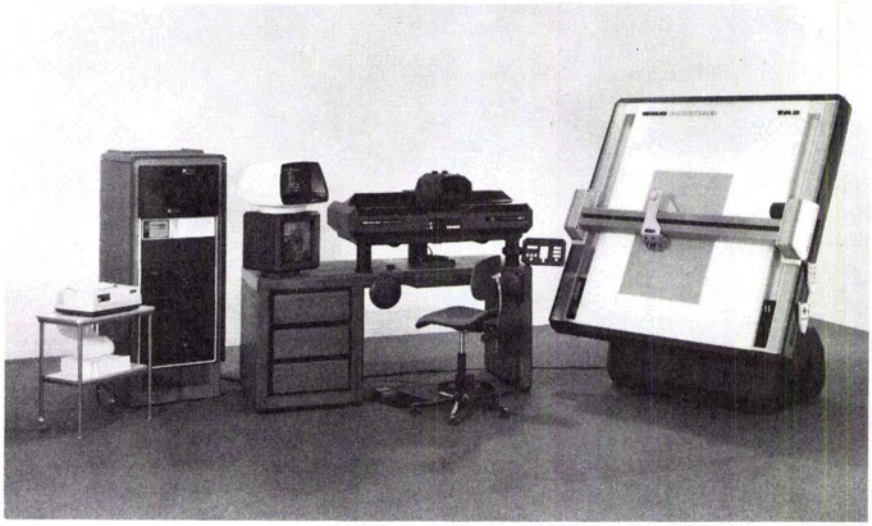

FRONTISPIECE. The Wild Aviolyt BC 1/Aviotab TA 2 computer-controlled photogrammetric system.

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The Analytical Stereoplotter Wild Aviolyt BC 1

This new low cost analytical stereoplotter fills a gap at the lower end of the range of analytical instruments for photogrammetric data acquisition.

(*Abstract on next page*)

INTRODUCTION

THE UPGRADING of conventional photogrammetric plotters to computer-supported data acquistion and mapping systems has in the past five to ten years influenced photogrammetric instrumentation to an increasing extent. Since the 1980 ISP-Congress in Hamburg there is, however, no doubt that the fully analytical plotter in a mature and practical form has succeeded in making the expected break-through in photogrammetry. The high expectations of users led to a first generation of analytical plotting systems which are characterized by universality, flexibility, comfort in use, and accuracy, but resulted inevitably in a high price. Such a system meeting the highest demands was presented for the first time by Wild Heerbrugg at the International Congress for Photogrammetry in Hamburg. The now already well-known computer-supported Aviolyt AC 1/Aviotab TA 2 plotting system has sucessfully been marketed since the middle of 1981. However, the persistent wish for a simpler plotter gave rise to the development of the Wild Aviolyt BC 1 as the latest addition to the range of analytical equipment.

CONCEPT AND OBJECTIVES

The main objective in the concept of the Aviolyt BC 1 was the realization of an analytical stereoplotting system for routine day-to-day photogrammetry at a price comparable with that of a second order conventional analog plotter. It is envisaged that the BC 1 will be employed on the following tasks:

- Direct plotting at medium and large scales (base maps, town and engineering plans);

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- Numerical data acquisition for cadastral measurements, interactive graphical systems, and databanks;
- Acquisition of digital terrain models and profiles;
- Data acquistion for the production of orthophotos; and
- Map revision.

With regard to the low target price, it was necessary to consider carefully to what extent trade-offs could be made in comparison with the first order Aviolyt AC 1 concerning accuracy, comfort in use, and universal performance and application. It was also clear from the beginning that the target price could only be maintained with extremely low development costs. From these considerations the following guiding principles evolved for the concept of the instrument:

- Implementation of the proven and tested system software of the Aviolyt AC 1 with minimum adaptation and the use of a software-compatible process computer of the Nova family;
- The use of the same types of service and control elements of the AC 1, however, reduced in number;

If the digital plotting table TA 2 is connected, the plotting system can be expanded to computer-supported direct plotting and fast or precise offline plotting (Frontispiece).

THE OPTICAL-MECHANICAL BASIC INSTRUMENT

The upper part of the optical-mechanical instrument contains the measurement and observation unit as well as part of the operation and control elements (functions keyboard, LED-coordinate display).

The upper part has three supporting legs, resting on the main supporting structure which has been modeled as a wooden desk.

Measuring and viewing devices. To keep the dimensions of the upper part of the instrument as small as possible, the two independent photo measuring systems each have an optical carriage (with viewing optics and measuring mark, moveable in the X-direction (base direction) and a photocarriage moveable in the Y-direction. The carriage drive system, which is independent of the measurement system, consists of friction drive and servo-controlled DC-motors with tachogenerator.

ABSTRACT: *This article describes hardware and performance characteristics of the new Aviolyt BC 1 analytical stereoplotter made by Wild Heerbrugg. The instrument is designed primarily for routine day-to-day photogrammetric work. Its principal use is envisaged in conjunction with the Aviotab TA 2 digital plotting table in direct graphic plotting at medium and large scales. The Nova 4/X process computer used in the Aviolyt AC 1 universal analytical stereoplotter and the practice-tested AC 1 system software are also adopted for the simpler Aviolyt BC 1.*

- High reliability by implementation of proven drive and guide components as well as of the servo systems;
- Provision for connection of the TA 2 digital drawing table and use of the same drawing software as with the AC 1.
- Precision of measurements corresponding to conventional mechanical precision plotters; and
- Possibility of expanding the basic system with optional extras such as zoom optics, measuring mark display, and free-hand guidance.

DESCRIPTION OF HARDWARE

The Aviolyt BC 1 photogrammetric plotting system consists of the following components:

- the optical-mechanical basic instrument with an integrated and centrally placed keyboard;
- a free-standing visual display unit (CRT);
- drive and control elements, located on the supporting structure;
- an electronics cabinet with computer, disk store, and magnetic tape unit (optional); and
- options to the basic instrument such as zoom, measuring mark display, and free-hand guidance.

The measuring range is 240 mm by 240 mm (9 by 9 inch) and has a three-step limitation (software, electrical, and mechanical.)

Photographs (glass plates and films) with a maximum format of 270 mm by 300 mm can be placed in the picture carrier (Figure 2) which is rigidly fixed to the Y-carriage. Square broad-line markings on the picture carrier permit the correct placement of the photographs to be measured. On both picture carriers nine grid crosses are etched with their precisely known coordinates stored in the computer. Using these, the instrument can be checked or re-calibrated at any time. Both picture carriers are accessible from the front of the instrument and are furnished with a plexiglass cover for protection against dust.

The measuring system comprises four linear encoders which have a resolution of 1 μm and consist of a fixed reading head and a glass scale placed on the X- or Y-carriage. Rectangularity and scale errors are determined by computer-assisted system calibration and are then automatically compensated in all subsequent measurements. Relative

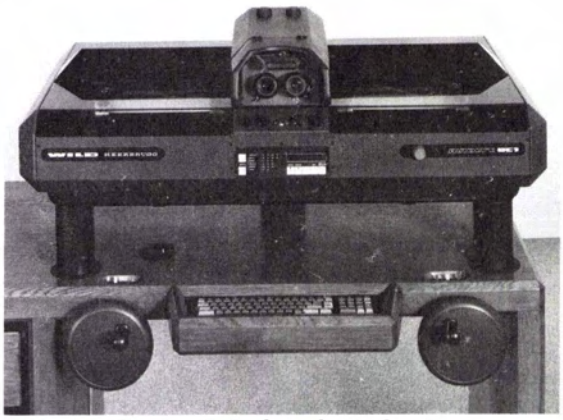

FIG. 1. Optical-mechanical unit.

height errors which may be caused by variations of room temperature are kept limited by special compensating device to an amount of ≤ 0.0006% per °C.

The viewing optics consist of a variable picture illumination using fluorescent tubes, the group of measuring marks, and the necessary lens elements. The measuring-mark group is a solid block containing two illuminated marks of different size and shape which can be switched over during measurment without loss of accuracy. The brightness can be varied. The viewing optics contain furthermore a changeover device for orthoscopic/pseudoscopic observation, dove prisms to correct image rotations of +130°/−35°, and interchangeable eye-pieces with 6-times and 9-times magnification, corresponding to a field of view of 30 mm and 20 mm, respectively. Eyebase variation from 55 mm to 80 mm, diopter compensation, and squint-error correction permit individual adjustment to the needs of different observers.

Zoom optics are available as an option and permit, in combination with the 6-times eye-pieces, a continuously variable magnification between 6-times and 20-times. The zoom optics can be set either independently for left and right photograph or can be coupled together.

Operation and control elements. The operation elements and control display are placed such that they can be comfortably reached or easily seen from the operator's position. The run of all programs can be controlled interactively by means of the alphanumeric keyboard, which is placed on the desk directly in the front of the observer and by means of the numerical CRT unit, which is located on the left of the upper part of the instrument. Function keys are only employed where their operation would cause the system to take immediate action, e.g., record. An eight-figure coordinate display (LED) is located directly in front of the operator's eyes. Using two display keys, the following coordinates can be selected for display: picture carriage, image, model, profile, terrain, and plotting-table. The kind of coordinate being display is indicated by an LED matrix. A set of keys below the coordinate display permit the following functions to act: HEIGHT (change of horizon), RECORD (automatic recording of coordinates), COMPLETE (straight line closure of polygon), NEXT POINT (go to the next point), and EXIT (finish of a measurement and exit from program).

Two handwheels, a foot-disk, and an incremental rotary control knob make possible a fine adjustment of a measuring mark's position. Separate fine, medium, and coarse movements for position (*X*,*Y*) and height (*Z*) can be set, using two 3-position rocker switches.

Three switches (*X*, *Y*, *Z*) permit a fast displacement of the measuring mark with a maximum speed of 30 mm/s in the photo plane.

Depending on the position of the positive and negative changeover switch, the sense of movement is determined by the program.

The profiling speed can be continuously varied by a regulator built into the desk surface.

The optional free-hand guidance which is also offered with the AC 1 is located on the open desk surface directly in front of the operator and permits a sensitive, continuous movement of the measuring mark or fast point location, depending on the selected transmission ratio. The operator can switch at any time from free-hand guidance to the *X*, *Y* handwheels. The option is particularly useful when plotting at large scales with the TA 2 digital-plotting table.

The display of measuring-mark position, which has been well received on the AC 1, can also be ordered as an option for the BC 1. An illuminated point, which is driven synchronously with the movement of the right measuring mark, indicates on a corresponding paper print of the right photo-

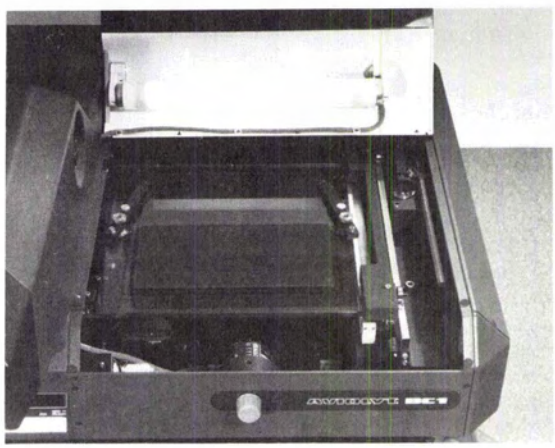

FIG. 2. Picture carriage and measuring system.

graph the current position. This can save time, particularly during the orientation phase.

A special functions-keyboard which can be mounted on the right hand supporting leg of the upper part of the instrument at a convenient distance provides computer-supported drawing when used with the TA 2 digital drawing table. A detailed description of this keyboard is given by Höhle *et al.* (1980).

Electronic drive and control unit. This unit, supplied as a module (plug-in circuit board), is located in the left-hand side of the supporting structure and represents the connecting element between the computer and the optical/mechanical basic instrument. The various printed circuits have the following functions: Servoamplifier and controller for the picture carriage and the measuring-mark display, input counter for all movement elements, signal processing of the switch instructions and status information on the functions keyboard and limit switches as well as input/output control via the interface and basic instrument.

The power supply for the control electronics and the basic instrument is also located in the lower support structure.

Further development of the instrument. With regard to the growing trend towards 9-inch by 18-inch format photography, mainly in the United States, the Aviolyt BC 1 will also be available in the near future as a special version for the plotting of such large format photographs.

An instruction eye-piece is planned as an option for the support of photointerpretation and the training of operators. This will permit the simultaneous observation of the stereoscopic model by two people.

A further option will permit the laterally correct observation of positives or negatives.

COMPUTER AND COMPUTER PERIPHERALS

The choice of the Nova 4/X minicomputer from Data General for the high precision and universal plotting instrument Aviolyt AC 1 (Kreiling and Hasler, 1980) proved in practice to be optimal with regard to performance and price. The criteria for the choice at that time are still valid and, consequently, the same process computer is also being used for the Aviolyt BC 1. This decision also offers the advantage that the fully developed and efficient software (Kreiling, 1982) of the Aviolyt AC 1 can be employed.

The 16-bit Nova 4/X computer with hardware multiply/divide unit and floating-point processor is provided as standard with a semiconductor core memory of 128 or 256 Kbyte. The combined magnetic disk/diskette unit with a storage capacity of 12.5/1.2 Mbyte or 25/1.2 Mbyte is an ideal medium for the storage of programs and large amounts of data.

Providing the computer with 256 Kbyte storage capacity and a second terminal enables also the simultaneous processing of time-uncritical application programs or the development of new programs (foreground/background mode) while the actual plotting is being undertaken in real time.

If required, a magnetic tape unit can be located and connected in the computer cabinet. A small printer or a faster line printer are available for the output of data sheets.

DIGITAL DRAWING TABLE AVIOTAB TA 2

The major application of the Aviolyt BC 1 will without doubt lie in direct plotting at medium and large scales. It is envisaged that the Aviotab TA 2 digital drawing table will economically fullfill this task, as it has with the AC 1. By implementing the entire AC 1 system software with its integrated drawing software, the BC 1/TA 2 plotting system can make use of all the possibilities by the computer-supported plotting of the AC 1/TA 2 system. A detailed description of the TA 2 and its drawing software can be found in Höhle *et al.* (1980) and Hohle and Jakob (1980). A report on the special performance characteristics of the TA 2 digital drawing table is given in Hohle (1982).

SOFTWARE

From the initial conception of the Aviolyt BC 1 it was decided to take over the software of the AC 1 practically unaltered, except for a few small modifications. From this result advantages primarily to the customers benefit:

- To a large extent the software based efficiency and variety of possible applications are carried over to the BC 1,
- Both instruments will profit to the same extent from current improvements and future developments of the software, and
- An operator trained on the AC 1 is able without additional training to use the BC 1 and vice versa.

The structure, advantages in use, efficiency, and scope of the common system software for the AC 1 and BC 1 are described seperately and in detail in Kreiling (1982).

IMPORTANT ACCURACY AND PERFORMANCE CHARACTERISTICS

- Resolution of the linear image coordinate measuring system $= 1\ \mu m$
- Repeatability of re-setting with 20× zoom magnification $\sigma_{x,y} \leq \pm 3\ \mu m$
- Absolute accuracy obtained from measurement of 25 grid points (mono), using a special 24× magnification:
  Standard coordinate error $\sigma_{x,y} \leq \pm 3\ \mu m$
  Max. error $e_{x,y} \leq \pm 5\ \mu m$

- Max. speed of travel (photograph) v_{max} = 30 mm/s
- Correction of the following parameters in real time program:
  - rectangularity and scale error of the picture carriage system
  - affine distortion of photograph
  - refraction and radially symmetric lens distortion
  - Earth curvature
- Average time required for
  - interior orientation with measurements of four fiducial marks — approx. 2 min.
  - outer orientation with six orientation points and four additional control points — approx. 5 min.

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