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CONFIGURATION AND PERFORMANCE FEATURES OF THE C-100 PLANICOMP ANALYTICAL STEREOPLOTTING SYSTEM

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1. Introduction

The C-100 PLANICOMP analytical stereoplotting system (Fig. 1) by CARL ZEISS of Oberkochen was introduced to the general public some 15 months ago on the occasion of the XIIIth International Congress of Photogrammetry in Helsinki /1/. Developed over a period of only 2 1/2 years, this analytical plotter is outstanding for its heretofore unknown degree of versatility and efficiency. Today, after a development period of almost four years, the first production series of this instrument is awaiting delivery to customers. While the general appearance of the PLANICOMP instruments from the first batch is still the same as that to the first prototype shown in Helsinki, their practical potential has been systematically improved and expanded by means of suitable software. This paper will therefore be devoted to a discussion of the capabilities of the system in its present form.

2. Basic concept of C-100 PLANICOMP

Basically, the C-100 has been conceived as a photogrammetric plotting system of very high accuracy, reliability, flexibility and economy, which will handle all ordinary plotting work normally encountered in photogrammetric production. In addition, it is designed to allow easy modification to accommodate even unusual work, making it suitable for use in research, training and special fields. Even now, however, the system is primarily oriented towards routine photogrammetric use where the success of an instrument is decided exclusively by reliability and productivity.

Development of the PLANICOMP focused on the following aims:

High accuracy commensurate with the performance of present-day mechanical precision equipment.

Computer-supported graphical plotting.

Computer-supported measurement of digital terrain models.

Computer-supported aerotriangulation.

Simplification of routine work such as orientation.

High operator comfort, making allowance for general operator preferences and using sophisticated new solutions.

Minimum training requirements so that operators experienced in handling mechanical analog instruments should be able to use the analytical plotter after a few hours' training, making full use of the system's capabilities after just a few days.

Computer-oriented design and computer-type operation during plotting should be limited to an absolute minimum in order to avoid routine chores being simplified merely at the expense of additional computer manipulations.

High reliability in conjunction with suitable error messages in clear text to warn against operating errors and unusual plotting procedure as well as suitable safeguards against power failure.

Price roughly identical to that of analog plotters of comparable performance, capability and accuracy.

Possibility of using the system's computer for general data-processing work.

Modular design of hardware and software suitable for expansion; in the case of software, expansion by customers familiar with FORTRAN.

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3. Description of hardware

3.1 Configuration

The C-100 PLANICOMP analytical stereoplotting system essentially consists of the measuring section, the control unit and the periphery. A basic opto-mechanical unit - the viewer - serves to view and measure the photographs. A photogrammetric control panel is located at its front. The two units are monitored separately by an electronic control unit, the so-called controller (Fig. 2). In addition, the control unit contains an interface for the minicomputer equipped with a disk storage, which with the aid of suitable software has a major part in controlling the plotting process in the PLANICOMP. A computer terminal in turn serves to control the computer. The terminal can also be used for clear-text output for the benefit of the operator. The system is suitable for modular expansion by connecting a DZ-6 ZEISS tracing table to the control unit and by adding commercial computer periphery.

3.2 The basic opto-mechanical unit

Due to its compact and self-contained design, the basic opto-mechanical unit (Fig. 3) can be set up on a simple desk-type frame. The housing contains two separate servo-driven systems of photo carriages moving in x and y and a fixed optical system for comfortable viewing. In front of the viewing unit is a control panel with switches for all important settings and processes, coordinate display and the drive elements such as handwheels, pedal disk, joy stick and speed control.

The photo carriages are designed as cross slides and driven by servomotors via precision lead screws. Their travel is 240 mm x 240 mm, limited by a three-stage stop system.

The photo carriers are rigidly connected to the carriages and cannot be rotated. Range marks are provided for rough positioning of photograms. In addition, a nine-point grid is provided for calibration.

The viewing system consists of an illuminator, a black measuring mark of 40 µm or 20 µm diameter and a stationary aerial image plane which is converted into a luminous floating mark by a variable light source, Dove prisms, a prism-control unit for change-over between orthoscopic and pseudoscopic stereo or binocular viewing of the left-hand and right-hand photos as well as slip-on eyepieces for 8x or 16x viewing magnification. The prism-control unit can be switched over manually or by computer, which is very useful above all during orientation.

3.3 The photogrammetric control panel

The control panel (Fig. 3) allows perfect control and checking of practically all operations required for orientation as well as numerical and graphical plotting. A keyboard marked "Instrument Status" serves to check on the functions "Viewer ON" (master switch), "Computer on-line" and "Table on-line" for connecting the computer or the tracing table.

Two handwheels and a pedal disk allow the floating mark to be moved around the stereomodel or over separate photos. In addition to the usual fine adjustment, a four-times higher speed is available by simple depression of a pedal. Moreover, a joy stick acting in x and y allows free-handed motion and, due to its non-linear action, even precise pointing. Another speed control in conjunction with a fixed angle input gives a profiling motion. The status of these input controls is defined by a panel of illuminated "Moving Status" keys: "Model Normal", "Model Terrestrial", Model Profiling", "Left and Right Photos", "Left Photo" and "Right Photo". With the aid of an additional toggle switch, the coarse/fine switch-over of the aforementioned pedal can be varied for change-over between common and parallactic photograph motion, which is very useful for direct shifting of photographs for clearing parallax during relative orientation.

There is another control panel for the viewing status featuring illuminated keys for "Binocular Left", "Binocular Right" and "Stereo" as well as a toggle switch for change-over from ortho to pseudo.

A coordinate display with four eight-digit registers has a three-stage toggle switch for the display of either ground, model or photo-carriage coordinates. In the case of ground or model coordinates, the fourth register may be used for other purposes, such as the display of point numbers.

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Considerable space on the control panel has been reserved for keys, switches and indicators for starting and controlling user programs. Of central importance is here the "Program Status" panel with the signal lamps "Busy" and "Standby" indicating whether the user programs are in progress, "Wait" indicating whether the user program in progress is waiting for a positive or negative decision by the operator in the form of a depression of one of the decision keys "Continue/Yes/Start" (with the second pedal being connected in parallel) or "Repeat/No/Stop", and a "Limit" indicator for the computer-controlled end positions of the photo carriages. The signals "Wait" and "Limit" are also given acoustically. A clearly offset "Execute" key interrupts the computer and causes it to read the status of the control panel so that a depressed program-selector key will be recognized and the corresponding program started. This means that up to the moment when "Execute" is pressed, any key that has been actuated by mistake will have no effect and can still be corrected.

The program-selector keys are subdivided into the blocks "Program Operation" and "Point Operation". The former block includes the permanently defined program keys "Parameter Control", "Interior Orientation", "Relative Orientation", "Absolute Orientation" and "Table Orientation" as well as the general keys "Call A Progr. No." and "Call B Progr. No.", which define further programs in conjunction with a program-code input via the decimal keyboard with input register. Beside this column of keys there are three toggle switches allowing up to three independent jumps to be selected in the corresponding user programs, for example, whether during relative orientation the first six Gruber parallax points should be approached automatically or manually.

The "Point Operations" block consists of keys for the programs MOVE TO, RECORD, DISPLAY, DELETE, STORE and CLEAR POINT MEMORY as well as the corresponding keys determining whether these programs refer to the image-coordinate memory or the ground-coordinate memory and whether only one photograph or only one ground coordinate is addressed.

In conjunction with a 12-digit input register, the aforementioned decimal keyboard allows input of the characters "-.0123456789" and erasure of the register as well as correction of the last character put into memory. It serves to input program codes, point numbers, coordinates and other code figures (for instance, for symbols).

In view of this design concept, the only operations remaining for conversation via the computer terminal (Fig. 4) (teleprinter or video screen) are a variation of the parameters of the COMMON data area that will be explained output of clear-text error messages and print-outs.

3.4 The electronic control unit

By control unit we shall here understand all electronic components operating between the basic opto-mechanical unit and the computer. In a wider sense, a few important operating functions of the computer, which are described in greater detail in the following section, also pertain to the control unit (Fig. 5).

The different functional assemblies of the control unit are: the power supply for the four photo-carriage drive assemblies, pulse counters, registers for carriage-shift values, input registers, key illumination and interlocking of key arrays, data conversion, clock-pulse generation as well as the control of computer input and output via interface.

The data to be supplied to the computer include the counted pulses of the drive elements, the content of the input register and the counter readings. The data received by the computer are, among other things, carriage-shift values, display coordinates, status information, switching commands for the optical control unit and the acoustic signals as well as erase instructions for the input register. Further details are of no importance for understanding the practical capabilities of the C-100 PLANICOMP.

3.5 The computer

The computer of an analytical stereoplotter has to satisfy various requirements. It should detect and convert handwheel motion into a displacement of the photo carriages, which in analog instruments is done by mechanical guide rods. In other words, the computer should read, process and transmit to the photo carriages and the tracing table the pulses counted at the handwheels and the pedal disk as often as is possible. The control is sufficiently free from inertia if the data are recomputed at least 40 times per second and if the shift values transmitted are converted into the corresponding linear motion by the servosystems before the next transmission is received.

In addition to high calculating speed, the computer should have high accuracy in order not to jeopardize the high accuracy of advanced photogrammetric techniques of 10^{-5} to 10^{-6}, equivalent to approx. 20 bits. In addition, there are further requirements which shall be mentioned here only briefly: rapid and easy access to programs, expandable periphery, auto-restart capability, sophisticated and intelligent operating programs, world-wide service and systems consultation as well as reasonable price.

In view of all these factors, the HP 21 MX minicomputer by Hewlett Packard (Fig. 5) was selected for the C-100 PLANICOMP, which for the purpose on hand is equipped with a semi-conductor storage capacity of 32 K-words and a disk storage unit of 4.9 Mbytes distributed over a fixed and an interchangeable disk. This type of computer has just recently become available with increased calculating speed and even faster semi-conductor memories, which further increase the processing speed by at least 100 %. The accuracy of this 16-bit computer is brought to the necessary level by so-called floating-point hardware without any noticeable loss in calculating speed. Further optional features are, among other things, memory protect, power-fail recovery, time-base generator, dual-channel port controller and disk-loader ROM. The computer terminal used is either a teleprinter or a video screen. In the latter case, a line printer is used as an additional subsystem for direct printout.

The storage capacity of the computer can be expanded up to a maximum of 256 K. All usual peripheral units such as tape reader and punch, tape deck, an additional disk unit, an independent line printer, etc., can be employed. The computer thus is clearly a multi-purpose unit that can be used for many different types of work, even if it is an integral part of the PLANICOMP system.

3.6 The tracing table

A DZ-6 digital tracing table, which is largely identical to the DZ-5 described elsewhere (Fig. 6), is provided for graphical work with the C-100 PLANICOMP. With an illuminated plotting area of 1200 mm x 1200 mm, an accuracy of 0.03 mm and a choice of different plotting tools, this table satisfies all present-day requirements for on-line plotting. Further characteristics of the DZ-6 are change-over between internal and external control, positioning with a separate joy stick for internal control, line dashing, cross plotting, manual lowering of plotting pencil by means of pedal switch by either one or two pedal despressions. Unlike the DZ-5, however, the DZ-6 does not allow positioning by coordinates and straight-line plotting. In the present case, these functions are taken over by the PLANICOMP software, since in the external mode the positioning commands and the lowering motion of the plotting pencil are controlled by the computer or the software. In conjunction with the C-100 PLANICOMP, the DZ-6 thus is much more efficient than the DZ-5, as will be borne out by a description of the user programs.

4. Description of software

4.1 Configuration

The software available for the PLANICOMP includes operating and user programs.

In the operating programs, the operating system is the program controlling computer operation and therefore is of overriding importance. Further operating programs serve for process control of the basic PLANICOMP unit and the control panel. The user programs include different groups of service programs supporting the operator and, possibly, separate computer programs installed by the customer (Fig. 5).

Since the system programs for editing, translating and loading new programs are also supplied, the PLANICOMP allows computer-supported measurement, independent computation and programming.

4.2 The operating system

The operating system is generally obtained from the computer manufacturer together with the computer and monitors the different functions, such as administration of memory contents, program control and triggering of peripheral equipment. The intelligent and expandable RTE II (Real Time Executive II) or III by HP was chosen for the C-100 PLANICOMP. The efficiency and components of RTE are characterized by multiprogramming, 99 priority levels, foreground/background or up to 64 partitions, communication and loader programs, device handler, file manager, compiler for FORTRAN, ALGOL, ASSEMBLER, etc. No further description will be given here, since in normal use PLANICOMP operators will not be confronted with RTE directly, but at best indirectly.

4.3 The operating programs

The operating programs consist of the LOOP and PANEL programs as well as of numerous operating routines. LOOP is periodically restarted every 20 msec, reads the pulses counted at the handwheels and the pedal disk or the joy stick of the PLANICOMP, adds them up to model coordinates and performs several transformation steps to compute the ground coordinates corresponding to the new model position as well as the new positions of photo carriages and tracing table and finally transmits the necessary shift values to the photo and table carriages (Fig. 8). This means that the LOOP program actually takes the place of the mechanical guide rod in analog mechanical instruments.

The input and output of differential quantities are combined with the transmission of certain status information required for LOOP computation, for example, whether ground, model or photocarriage coordinates should be displayed on the control panel, whether planimetry or vertical elevation should be plotted on the tracing table or whether table control is unnecessary because there is no table connected to the machine. If, moreover, no shift increments have been input via the controls, only input and output will be performed and the different transformation steps need not be computed. In this case, LOOP comes to an end after less than 1 msec so that at least 19 msec are available for other computations (service programs or background programs). In the case of photo drive, LOOP takes less than 5 msec, in the least favorable case of model motion about 9 msec.

The PANEL program is started by the "Execute" key of the control panel. It reads and analyzes the position of keys and switches that cannot be read by LOOP as well as the input register of the control panel and starts the desired user program. PANEL thus only serves to initiate the user program selected.

As examples of operating routines we might mention the subroutines LIGHT, CORE, MOVE, NUREG, which allow user programs to act on the status display, the numerical input register as well as the photo carriages and the tracing table and to activate the decision keys "Continue/Yes/Start" and/or "Repeat/No/Stop". With the aid of these routines that can be called by usual FORTRAN statements, users will later be able to write their own interactive programs.

4.4 The service programs

While some of the operating programs and subroutines are for various reasons written in ASSEMBLER, all user programs have been written in FORTRAN in order to facilitate subsequent modification to make allowance for practical experience or for special applications. At present, standard equipment of every PLANICOMP system includes about 75 service programs. However, the number of problems that can be solved is far greater, since numerous programs allow different uses due to jumps that can be selected on the control panel.

One characteristic of the software structure that is essential for the operation of the PLANICOMP is the subdivision of the service programs into three priority levels: A-programs of high, B-programs of medium and C-programs of low priority. This subdivision makes allowance for the fact that a human operator will frequently perform secondary operations during his primary work (B-level) or procure additional information required for further operation (A-level). Moreover, certain types of work will frequently be performed, the results of which are not directly related to the work in progress at a given time (C-level). This is why a subdivision into brief programs (A), main programs (B) and background programs (C) was chosen. Simultaneously called programs of identical or different priority will be executed following the rule that in the case of programs of identical priority the one started last will kill the one in progress, that a program of higher priority interrupts one of lower priority and that an interrupted lower program will be resumed only after the end or suspension of all other higher-priority programs that may be in progress.

All service programs are combined in several categories that are permanently assigned to different priority levels (Fig. 9): all programs for numerical processing and automatic plotting to the C-level; orientation procedures, DTM measurement, linear, computer-supported plotting, etc., to the B-level; all data manipulations, simple measurement procedures as well as plotting symbols and lettering to the A-level.

In the following, a brief description will be given of the different service programs presently available (Fig. 10).

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Automatic plotting

GRID PLOTTING plots a rectangular map grid (grid intersections or network of lines) with variable grid interval and using any desired quatrilateral as a map frame, with or without coordinate lettering.

POINT PLOTTING plots all desired points available in a file with variable type and size of symbols at any desired scale, adding the point number.

VECTOR PLOTTING plots all vectors stored in a file at any desired, variable scale for point location and vector length.

Numerical processing

ATM STRIP and ATM BLOCK are two programs developed by the Institute of Photogrammetry of Stuttgart University for the PLANICOMP for the strip or block adjustment of stereo models /2/.

POINT CORRECTION corrects all points stored in a file by interpolation in a vector field given in another file.

DISTRIBUTION computes the statistical distribution of a geometrical quantity stored in a file, plus correlation should the quantity be two-dimensional.

On-line plotting

PLOT ONLINE supports the direct plotting of straight lines, polygons, circular arcs and spline curves and automatically fills in the third and fourth sides of houses of which three points have been plotted (parallelogram).

DTM measurement

RECORD TERRAIN MODEL controls the single and incremental recording of any desired array of lines using increments of time, travel or height of variable magnitude as primary and secondary increments.

RECORD TERRAIN PROFILE allows incremental recording as in the aforementioned program, following a planimetric back-and-forth pattern with variable speed as well as variable number, direction, length and interval of profiles.

RECORD TERRAIN GRID controls automatic recording on crossing the grid lines of a freely chosen rectangular network, regardless of motion direction, or will automatically position to a defined network for the purpose of statistical grid measurement.

RECORD CROSS SECTION requires input or measurement of a route for which a cross-section grid of variable position and length is then computed, which is used as a basis for planimetric control for the purpose of cross-sectioning, travelling speed being variable. There is a choice of individual and incremental triggering of recording.

All DTM programs are flexible as regards format and recording address.

Orientation

INTERIOR ORIENTATION controls interior orientation by automatic coarse pointing of the fiducial marks to be measured and computes the position of the photograms on the photo carriages and thus the transformation parameters required for LOOP after fine adjustment of each of the marks (either two or four fiducial marks per photo). If four fiducial marks are measured, allowance is made for affine film shrinkage.

RELATIVE ORIENTATION requires a minimum of six and a maximum of 24 parallax measurements, the Gruber points being approached for the first six, if it is so desired. The program then computes the parameters of relative orientation by the condition of collinearity, using an adjusting formula and the necessary number of iterations and preserving either the left-hand or the right-hand photo at the operator's choice. Next, the program displays the residual parallax including the mean value on the terminal. The result of orientation becomes effective only after the operator has approved it by depression of the "Yes" key on the control panel. (For additional possibilities for bridging, see item 5.)

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ABSOLUTE ORIENTATION is used for both independent orientation and bridging (item 5) and may take into account up to 24 measurements of partial or fully fledged control or tie points in any desired order. At least two horizontal and three vertical control points have to be measured for independent orientation. A comparison with the control data stored in the computer is in any case made by an adjusting formula and after the necessary number of iterations will give corrections of orientation which in turn will become effective only after the operator has accepted the residual errors at the control points. These are, however, displayed only in the case of overdetermination.

TABLE ORIENTATION computes the parameters of correlation required for LOOP after measurement of two identical points in the stereo model and on the plotting sheet. If additional points are measured (max. 24), an adjustment will be made and affine paper shrinkage will be taken into account, provided that the operator makes allowance for residual errors at the map points.

Plotting symbols and lettering

PLOT SYMBOL allows the plotting of symbols from a programmed supply of characters and the addition of figures, such as point number, elevation or planimetric coordinate, the size, position and rotation of characters being variable.

PLOT ALPHA allows the plotting of text input on the terminal (any ASC II character available on the terminal keyboard may be used), size, rotation and position again being variable.

Simple measurement

POINT OPERATIONS is a group of minor programs that are of considerable importance for point measurement during orientation and recording:

MOVE TO POINT checks the automatic approach of stored points or entered ground coordinates.

RECORD POINT records the instantaneous position of the measuring mark in the desired format on a desired peripheral unit.

STORE POINT stores the instantaneous position or ground coordinates input via the control panel in the desired point memory.

DISPLAY POINT displays stored coordinates on the terminal.

DELETE POINT deletes separate points from the memory either entirely or individual coordinates only.

CLEAR POINT MEMORY erases all points in the point memories, either complete or individual coordinates only, such as all z-ground coordinates, etc.

The CALCULATE "element" programs (element being CENTER, DISTANCE, LENGTH, SLOPE, ANGLE, AZIMUTH, AREA or VOLUME) allow measurement, computation and storage of geometric quantities, such as the computation of the center of gravity of n points (also suited for averaging in the case of repeated pointing), computation of horizontal/vertical distances, the length of straight lines or curved lines in space, the determination of solid angles, azimuth or slope angles, of areas and volumes, the latter with either continuous or step-by-step tracing of boundaries.

Data manipulation

A multitude of additional programs serve for sorting the most varied kinds of data, for correcting, erasing, shifting or input and output.

PARAMETER CONTROL allows the display or variation of important parameters in the interactive mode on the computer terminal.

The group of LIST programs prints out in clearly legible form on the computer terminal or the printer the model data in one of four languages, the contents of point memories, camera data, calibration data, etc., so that printed records are available.

Further data-manipulating programs serve either generally or specifically for data transmission between working memory and disk memory or between disk memory and peripheral unit and will therefore be discussed under 4.5 together with a description of the different files available.

Further service programs that will not be discussed in greater detail here are TRANSFORM ORIENT DATA for computing orientation data for analog plotters from PLANICOMP orientation data, C-100 CALIBRATION for measurement support and computation of grid measurements for the purpose of calibration and C-100 FUNCTION TEST for computer-controlled functional checkout of the PLANICOMP.

4.5 The file structure

The working memory of the computer is always occupied by the operating system, the LOOP operating program and the COMMON data area that is always accessible to all programs. The storage capacity (Fig. 11) thus remaining for the disk-residing programs that are loaded into the memory upon request only should not drop below a certain minimum in order not to complicate programming. It follows from this that the COMMON data area should be kept "small", since the extent of the operating system and of LOOP cannot be influenced. Since, moreover, the COMMON area already has to include all parameters of control, orientation, transformation and plotting (for LOOP as well as most of the service programs), it can accommodate only a limited amount of measurement data and control points (image coordinates for 24 points, ground coordinates for 48 points).

Large files have therefore been included in the disk memory, whose size can be varied by the operator:

The "Ground File" is intended as a control-point memory and can accommodate, for example, some 10,000 control points;

the "General Files" will store different measurement data in a variable format and are thus general-purpose data memories for the operator. These files are generally subdivided into sections of different size and will accommodate about 50,000 recordings, for example;

the "Orient File" is intended for storing orientation data, for instance, for a few hundred models in the way of a model bank so that all models that have been oriented once can be reconstructed very quickly;

the "Common File" is intended for storing a few complete contents of the COMMON area and thus allows complete machine states to be "frozen" for subsequent analysis (above all, for testing and servicing).

Data transfer from and to these files is handled by the corresponding program groups (Fig. 12):

READ/RECORD ... FILE (... = ORIENT, GROUND, GENERAL or COMMON) controls the transfer from or to the peripheral units.

SAVE/ENTER ... FILE controls transfer from or to the working memory of the computer.

LIST ... FILE indicates file availability on the computer terminal.

CLEAR ... FILE erases the file either completely or partly.

5 Performance characteristics

The description of hardware and software has shown that the C-100 PLANICOMP analytical stereoplotting system can, without any difficulty, be used directly for practically any kind of plotting work encountered in present-day photogrammetric practice:

Graphical plotting

Direct line plotting.

Computer-supported line plotting.

Computer-supplemented line plotting.

Interactive plotting of symbols, figures and text.

Fully automatic plotting of grids, groups of points and vectors.

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Digital terrain models

Recording of points.
Incremental line tracing.
Computer-guided profiling.
Computer-guided grid measurement.
Computer-guided cross-sectioning.

Aerotringulation

Automatic movement to tie points.
Bridging for computer checking of tie and control point measurements.
Data storage in the form of model or bundle coordinates.
Model triangulation by strips.
Model triangulation by blocks.

Special purposes

Measurement of geometric quantities.
Statistic testing of geometric quantities.
Orientation data for analog plotters.
"Model bank"
Civil-engineering surveys.

It may be expected that the multitude of economical applications of this plotting system will be increased even further in the future.

References:

/1/ Hobbie, D.: C-100 PLANICOMP, the analytical stereoplotting system from CARL ZEISS of Oberkochen; Presented Paper, Comm. II, XIIIth Congress of Photogrammetry, Helsinki, 1976.

/2/ Klein, H.: Aerotriangulation with C-100 PLANICOMP and the Stuttgart programs; paper published for 36th Photogrammetric Week, Stuttgart, 1977.

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Abstract

The paper introduces the C-100 PLANICOMP analytical stereoplotting system by CARL ZEISS of Oberkochen, discussing its design, software and performance. The system consists of a basic opto-mechanical unit, a photogrammetric control panel, control unit, computer, computer terminal in the form of a teleprinter or video screen, peripheral equipment and tracing table. In conjunction with some 75 user programs, it offers a multitude of advantages over analog equipment: rapid and objective adjusting orientation with output of residual errors; single and incremental recording with great flexibility regarding increments, measurement setup and output format; aerotriangulation with direct data checking during measurement and subsequent overall adjustment in the instrument without data transfer; computation of secondary geometric quantities such as center of gravity, distance, length, angle, area, volume; computer-supported graphical plotting (on-line mode) of straight lines and spline curves, supplementary plotting, plotting of symbols, point numbers, spot heights, lettering as well as fully automatic plotting of grids, points and arrays. At a cost comparable to that of larger analog systems, a "photogrammetric plotting center" has thus become available, which already now makes allowance for future developments going well beyond its present capabilities.

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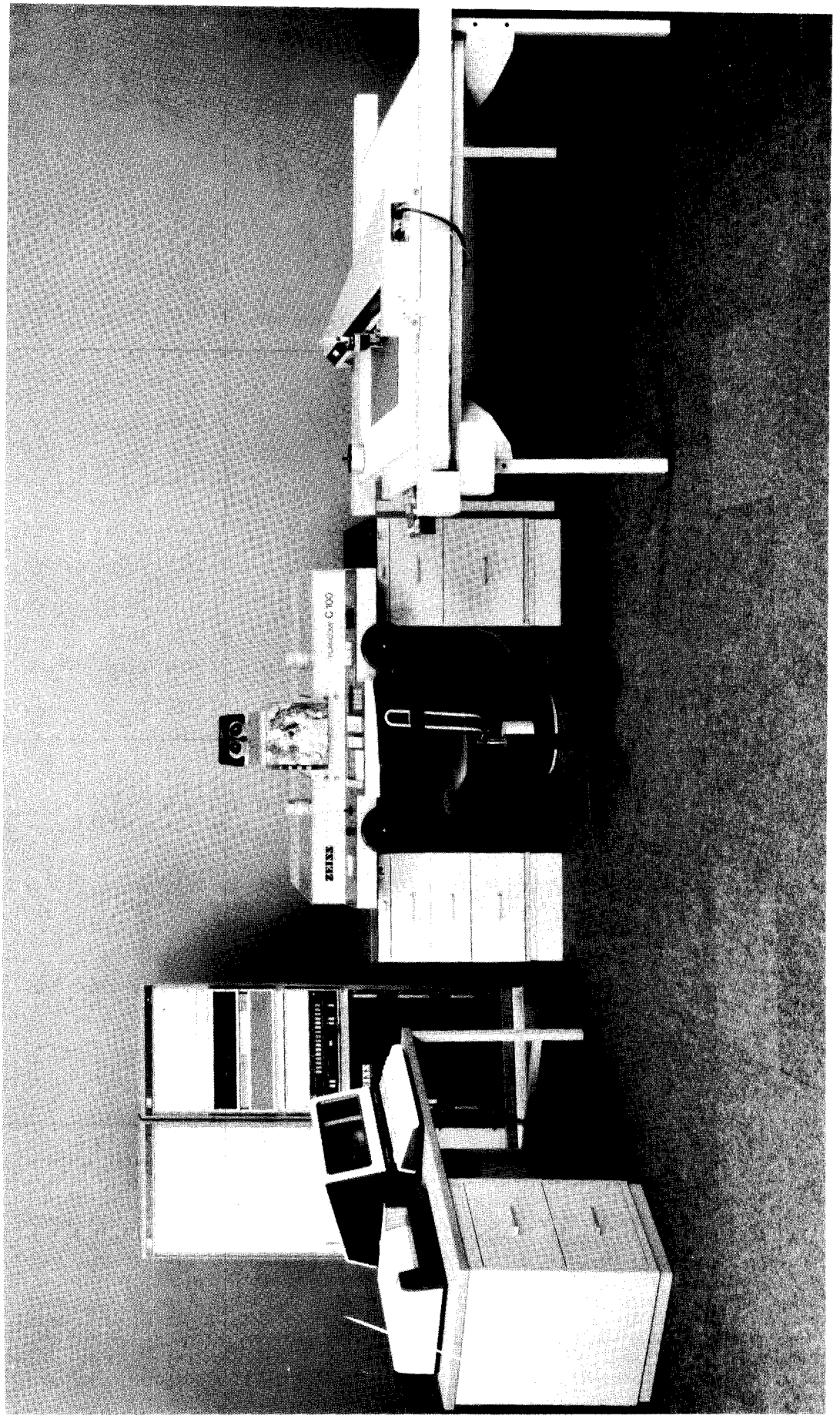

Fig. 1: The C-100 PLANICOMP analytical stereoplotting system by CARL ZEISS of Oberkochen; with DZ-6 tracing table.

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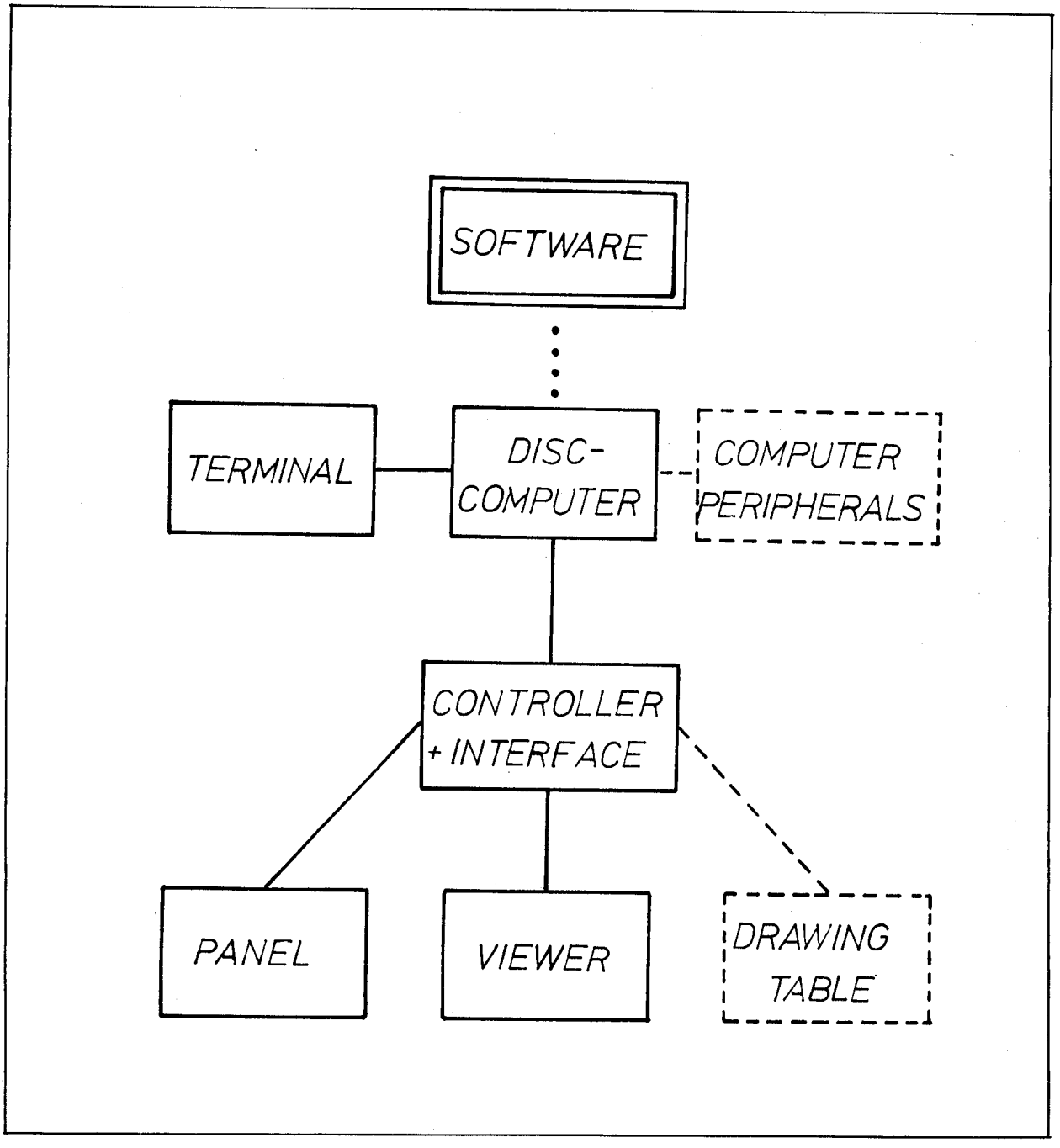

Fig. 2: Hardware configuration of C-100 ZEISS PLANICOMP.

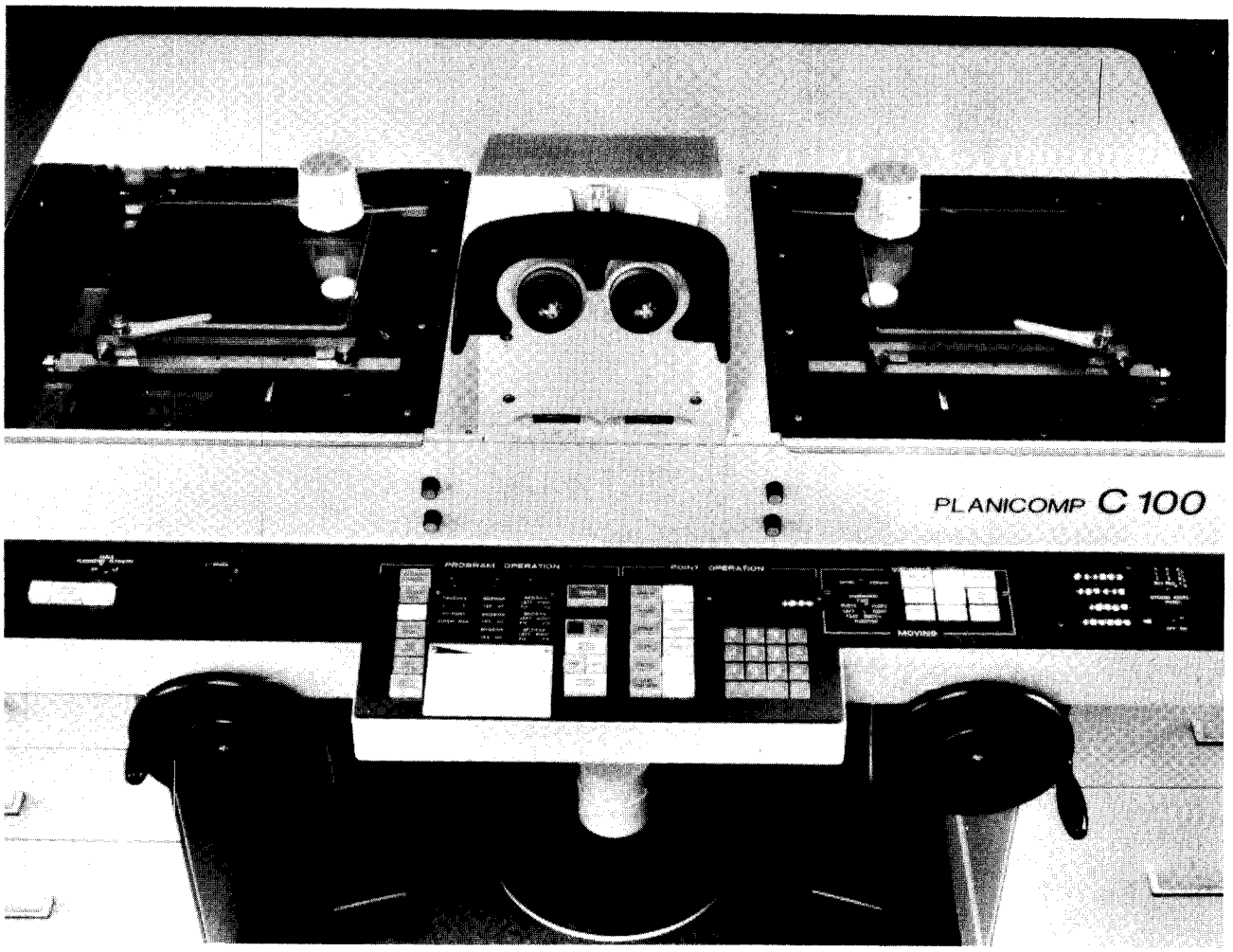

Fig. 3: Control panel and photo carriages of basic opto-mechanical unit of C-100 PLANICOMP

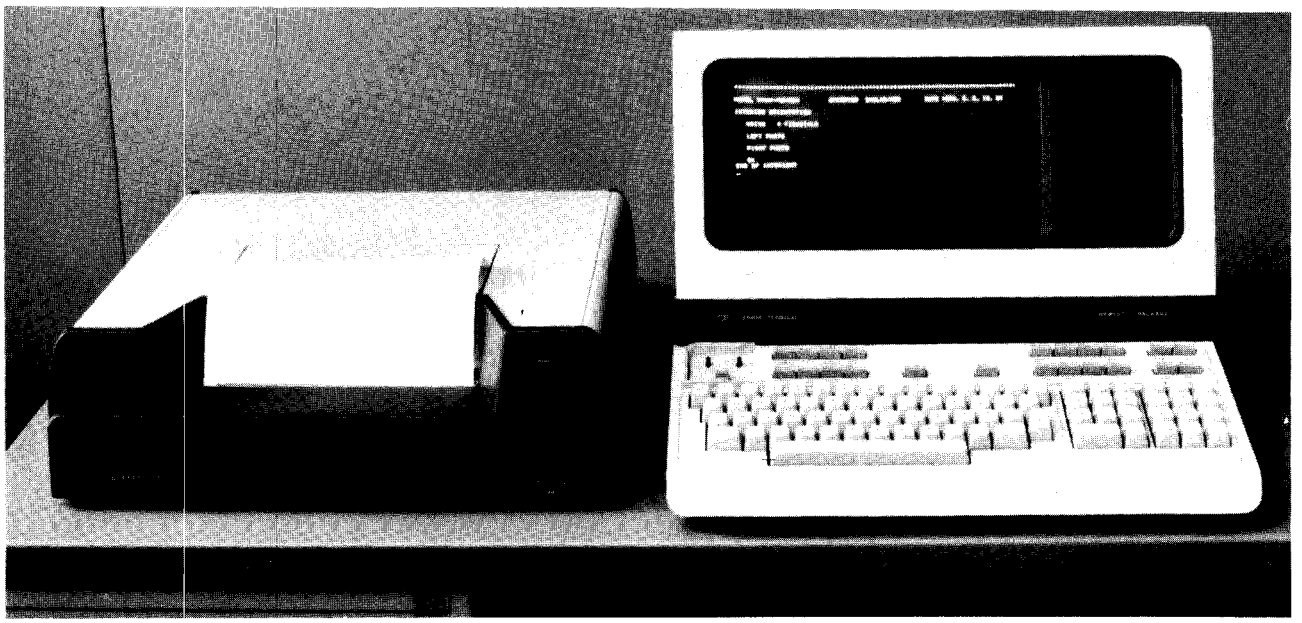

Fig. 4: Video display unit and line printer.

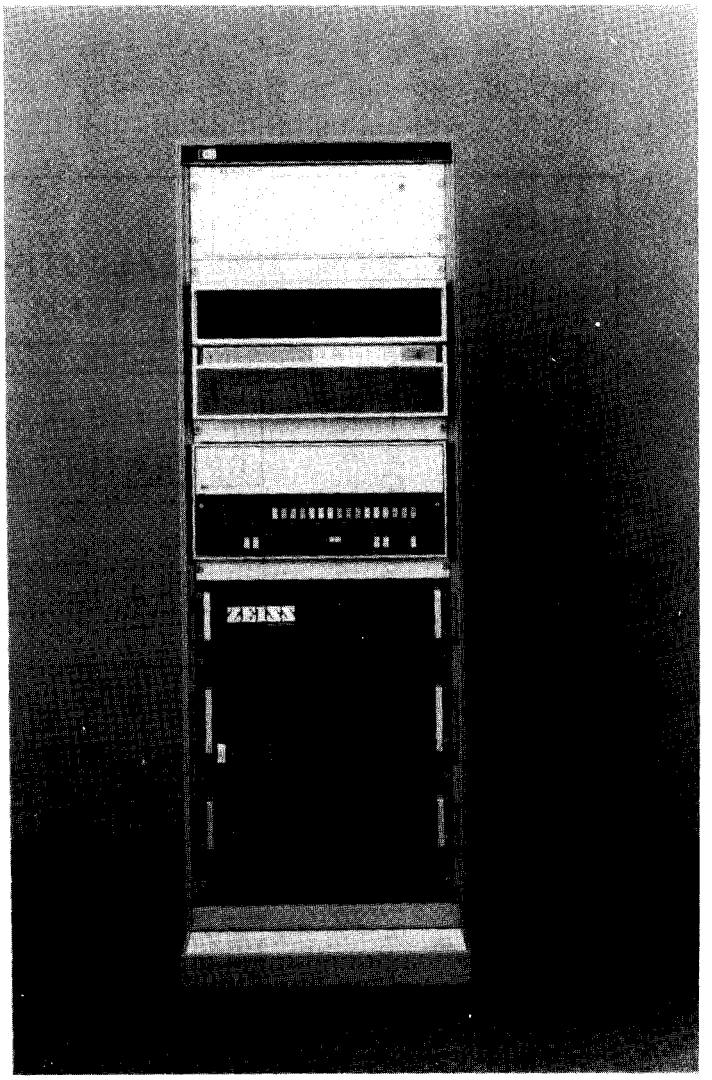

Fig. 5: Computer and control unit of C-100 PLANICOMP.

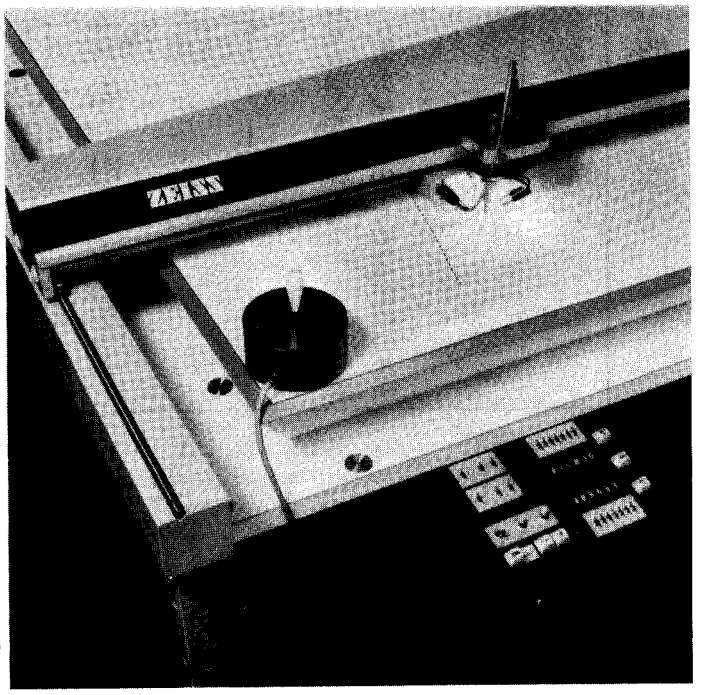

Fig. 6: The DZ-6 digital tracing table (detail).

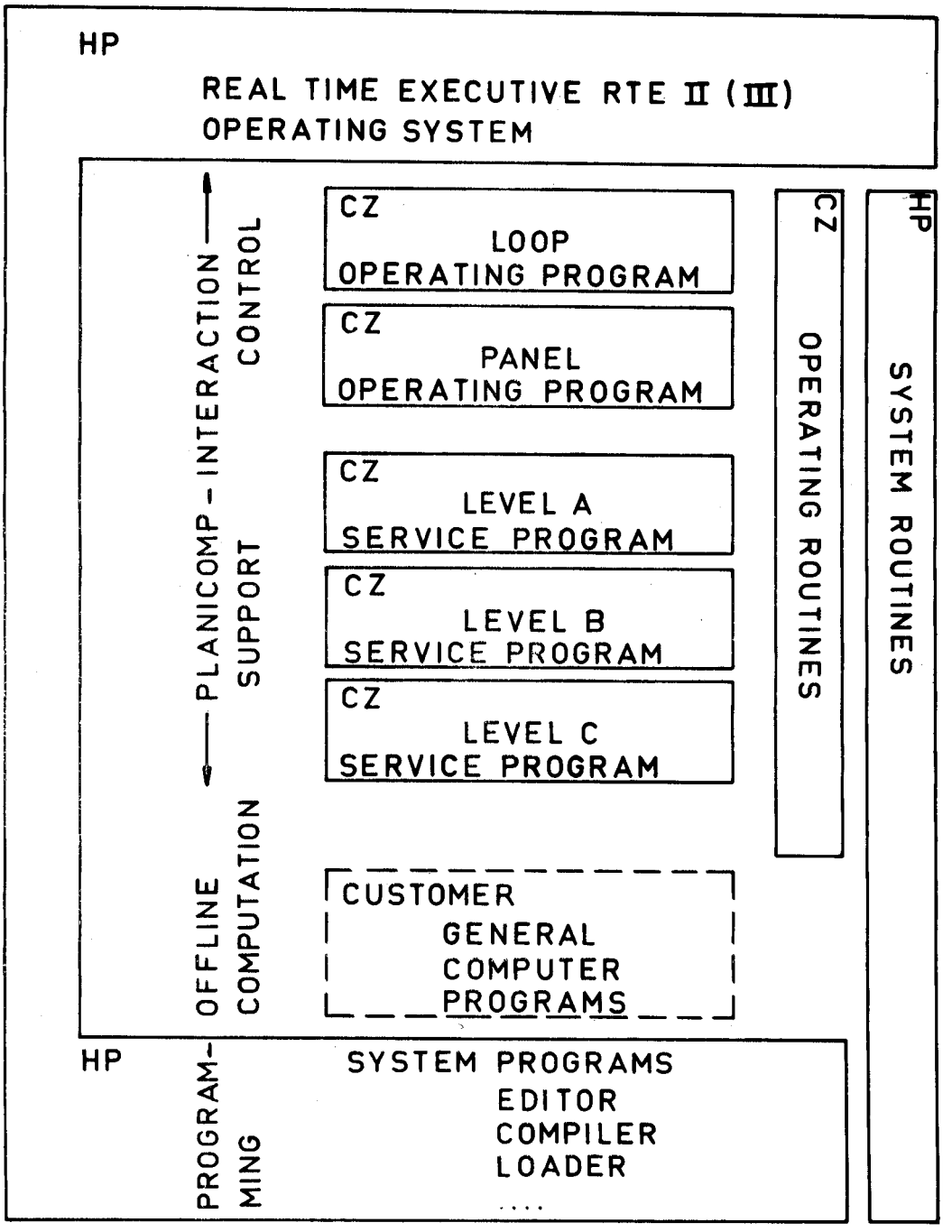

Fig. 7: Software configuration of C-100 PLANICOMP.

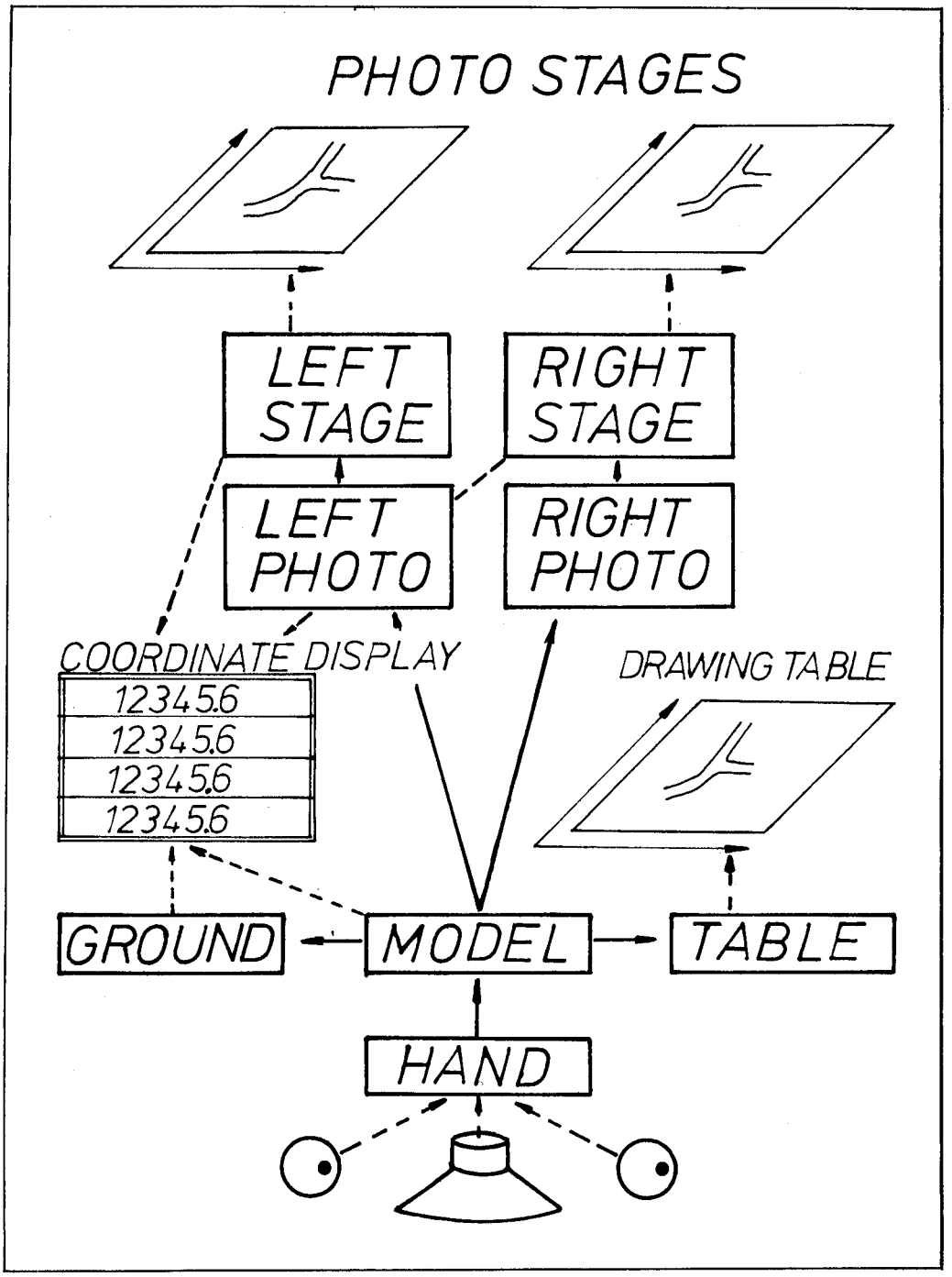

Fig. 8: Computation of coordinate transformation by PLANICOMP operating program LOOP.

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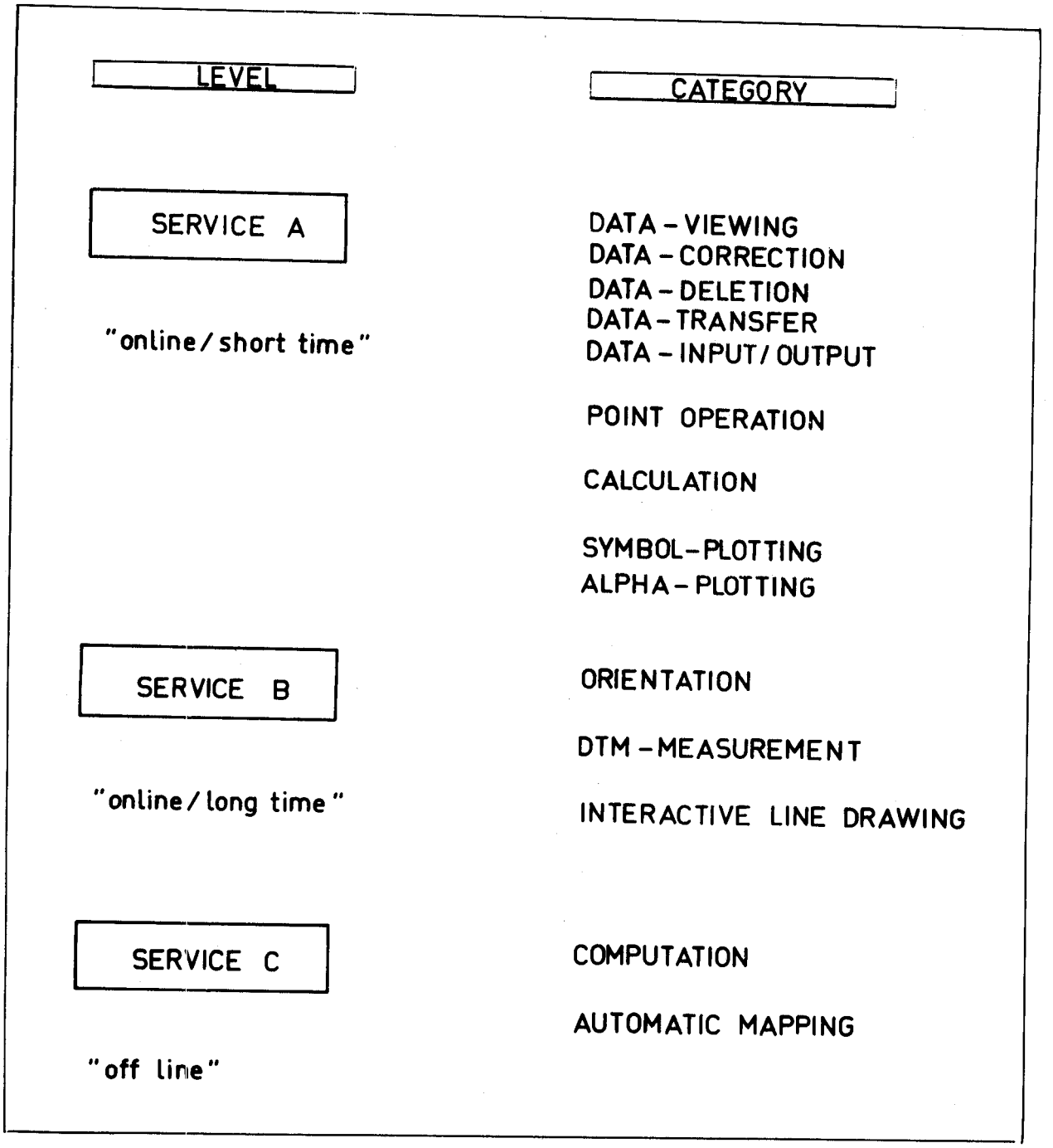

Fig. 9: Classification of service programs.

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```
LIST LIBRARY

   LIBRARY OF SERVICE PROGRAMS FOR ZEISS PLANICOMP NO.127681  1977.12.12
   ------------------------------------------------------------------------
   ADRESS     NAME                          DESCRIPTION

   B  2* INTERIOR ORIENTATIOM  MEASUREMENT SUPPORT, COMPUTATION, REPORT
   B  3* RELATIVE ORIENTATION  MEASUREMENT SUPPORT, COMPUTATION, REPORT
   B  4* ABSOLUTE ORIENTATION  MEASUREMENT SUPPORT, COMPUTATION, REPORT
   B  5* TABLE    ORIENTATION  MEASUREMENT SUPPORT, COMPUTATION, REPORT
   A  6  MANUAL   ORIENTATION  CONTROL OF INCREMENTAL PARAMETER CHANGE

   A  8* PARAMETER CONTROL    DISPLAYS, SUPPORTS CHANGE OF PARAMETERS
   A  9* MOVE TO              MOVES TO STORED POINTS, ENTERED COORDINATES
   A 10* RECORD               RECORDS POSITION ON TERMINAL & PERIPHERALS
   A 11* DISPLAY              DISPLAYS STORED POINTS ON TERMINAL
   A 12* STORE                STORES POSITION/ENTERED POINTS IN MEMORY
   A 13* DELETE               DELETES POINTS/COORDINATES IN MEMORY
   A 14* CLEAR POINT MEMORY   CLEARS MEMORY COMPLETELY/COORD.ARRAYS ONLY

   A 20  LIST MODEL DATA ENGL  WRITES ENGLISH REPORT ON MODEL ORIENTAT.
   A 21  LIST MODEL DATA GERM  WRITES GERMAN  REPORT ON MODEL ORIENTAT.
   A 22  LIST MODEL DATA FREN  WRITES FRENCH  REPORT ON MODEL ORIENTAT.
   A 23  LIST MODEL DATA SPAN  WRITES SPANISH REPORT ON MODEL ORIENTAT.
   A 24  LIST GROUND MEMORY    LISTS CONTENT OF GROUND COORDINATE MEMORY
   A 25  LIST PHOTO MEMORY     LISTS CONTENT OF PHOTO COORDINATE MEMORY
   A 26  LIST CAMERA DATA      LISTS DATA OF ACTUAL PHOTOGRAPHS
   A 27  LIST TRANSFORM. DATA  LISTS GROUND, MODEL, TABLE PARAMETERS
   A 28  LIST CALIBR. DATA     WRITES CALIBRATION REPORT
   A 29  LIST PROGRAM LIBRARY  LISTS LIBRARY OF SERVICE PROGRAMS

   A 30  LIST   ORIENT FILE  LISTS MODEL NAMES OF ORIENT FILE ON DISC
   A 31  CLEAR  ORIENT FILE  CLEARS ORIENT FILE ON DISC
   A 32  SAVE   ORIENT DATA  STORES ORIENTATION DATA  ON  ORIENT FILE
   A 33  ENTER  ORIENT DATA  ENTERS ORIENTATION DATA FROM ORIENT FILE
   A 34  RECORD ORIENT DATA  TRANSFERS DATA FROM ORIENT FILE TO PERIPH
   A 35  READ   ORIENT DATA  TRANSFERS DATA FROM PERIPHERAL TO ORNT FILE
   A 39  TRANSFORM ORI DATA  TRANSFORMS ORIENTATION DATA FOR PLANIMAT,
                               PLANICART, PLANITOP & STEREOPLANIGRAPH

   A 40  LIST   GROUND FILE  LISTS GROUND CONTROL DATA AVAILABLE ON DISC
   A 41  CLEAR  GROUND FILE  CLEARS GROUND CONTROL DATA ON DISC
   A 42  SAVE   GROUND DATA  STORES GROUND MEMORY CONTENT ON GROUND FILE
   A 43  ENTER  GROUND DATA  ENTERS GROUND CONTROL DATA FROM GROUND FILE
   A 44  RECORD GROUND DATA  TRANSFERS DATA FROM GROUND FILE TO PERIPH
   A 45  READ   GROUND DATA  TRANSFERS DATA FROM PERIPHERAL TO GRND FILE
   A 46  FIND   GROUND DATA  ENTERS CONTR. POINTS DEFINED BY AREA BOUNDS

   A 50  LIST   GENERAL FILE  LISTS HEADER & CONTENT OF GENERAL FILES
   A 51  CLEAR  GENERAL FILE  CLEARS GENERAL FILE CONTENT ON DISC
   A 52  TRANSFER GEN.  DATA  TRANSFERS DATA BETWEEN GENERAL FILES
   A 54  RECORD GENERAL DATA  TRANSFERS DATA FROM GENERAL FILE TO PERIPH
   A 55  READ   GENERAL DATA  TRANSFERS DATA FROM PERIPHERAL TO GEN FILE
   A 56  EDIT   GENERAL DATA  SUPPORTS CORRECTION OF GEN FILE CONTENT
   A 58  SAVE   ATB DATA      STORES BUNDLE-TRIANGULATION DATA ON GEN FIL
   A 59  SAVE   ATM DATA      STORES MODEL-TRIANGULATION DATA ON GEN FILE
```

Fig. 10: Service programs for C-100 PLANICOMP (Part 1).

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A 60  CALCULATE CENTER     CALCULATES AND MOVES TO CENTER OF N RECORDS
A 61  CALCULATE DISTANCE   CALCULATES HORIZONTAL/VERTICAL DISTANCES
A 62  CALCULATE LENGTH     CALCULATES LENGTHS OF STRAIGHT/CURVED LINES
A 63  CALCULATE SLOPE      CALCULATES VERTICAL ANGLES FROM 2 POINTS
A 64  CALCULATE ANGLE      CALCULATES SPATIAL ANGLES BETWEEN 3 POINTS
A 65  CALCULATE AZIMUT     CALCULATES HORIZONT. ANGLES AGAINST +Y-AXIS
A 66  CALCULATE AREA       CALCULATES PLANIMETRIC SIZE OF AREAS
A 67  CALCULATE VOLUME     CALCULATES SIZE OF HORIZONT. CUT VOLUMES
C 69  DISTRIBUTION         COMPUTES STATISTICAL DATA FOR STORED DATA

B 70  RECORD TERRAIN MODEL    CONTROLS SINGLE/INCREMENTAL RECORDING
B 71  RECORD TERRAIN PROFIL   CONTROLS XY-SCAN, INCREMENTAL RECORDING
B 72  RECORD TERRAIN GRID     CONTROLS GRIDLIKE RECORDING
B 73  RECORD CROSS SECTION    CONTROLS CENTERLINE/CROSS SECTION RECORD

B 80  PLOT ONLINE          SUPPORTS GRAPHICAL ONLINE PLOTTING
A 81  PLOT SYMBOL          GENERATES NUMERIC CHARACTERS/SYMBOLS
A 82  PLOT ALPHA           GENERATES ALPHANUMERIC CHARACTERS/SYMBOLS
C 85  GRID PLOTTING        CONTROLS PLOTTING OF A GRID
C 86  POINT PLOTTING       CONTROLS PLOTTING OF STORED POINTS
C 87  VECTOR PLOTTING      CONTROLS PLOTTING OF STORED VECTORS

A 90  LIST   COMMON FILE   LISTS MODEL NAMES OF COMMON FILE ON DISC
A 91  CLEAR  COMMON FILE   CLEARS COMMON FILE ON DISC
A 92  SAVE   COMMON DATA   STORES COMMON DATA  ON  COMMON FILE
A 93  ENTER  COMMON DATA   ENTERS COMMON DATA FROM COMMON FILE
A 94  RECORD COMMON DATA   TRANSFERS DATA FROM COMMON FILE TO PERIPH
A 95  READ   COMMON DATA   TRANSFERS DATA FROM PERIPHERAL TO COMM FILE
A 96  SET    COMMON DATA   RESETS COMMON DATA SECTIONS
A 97  LIST   COMMON DATA   LISTS COMMON DATA ON TERMINAL
B 98  C100 CALIBRATION     MEASUREMENT SUPPORT, COMPUTATION, REPORT
C 99  FUNCTION TEST        CONTROLS CHECK OF C100-HARDWARE FUNCTION

C101  POINT CORRECTION     IMPROVES STORED POINTS BY VECTOR MATRIX
C105  ATM STRIP            COMPUTES STRIP ADJUSTMENT FOR MODELS

    * PROGRAMS WITH *-LABELED ADRESSES ARE CALLABLE
      FROM EXCLUSIVE PANEL KEYS

END OF LIST LIBRARY
```

Fig. 10: Service programs for C-100 PLANICOMP (Part 2).

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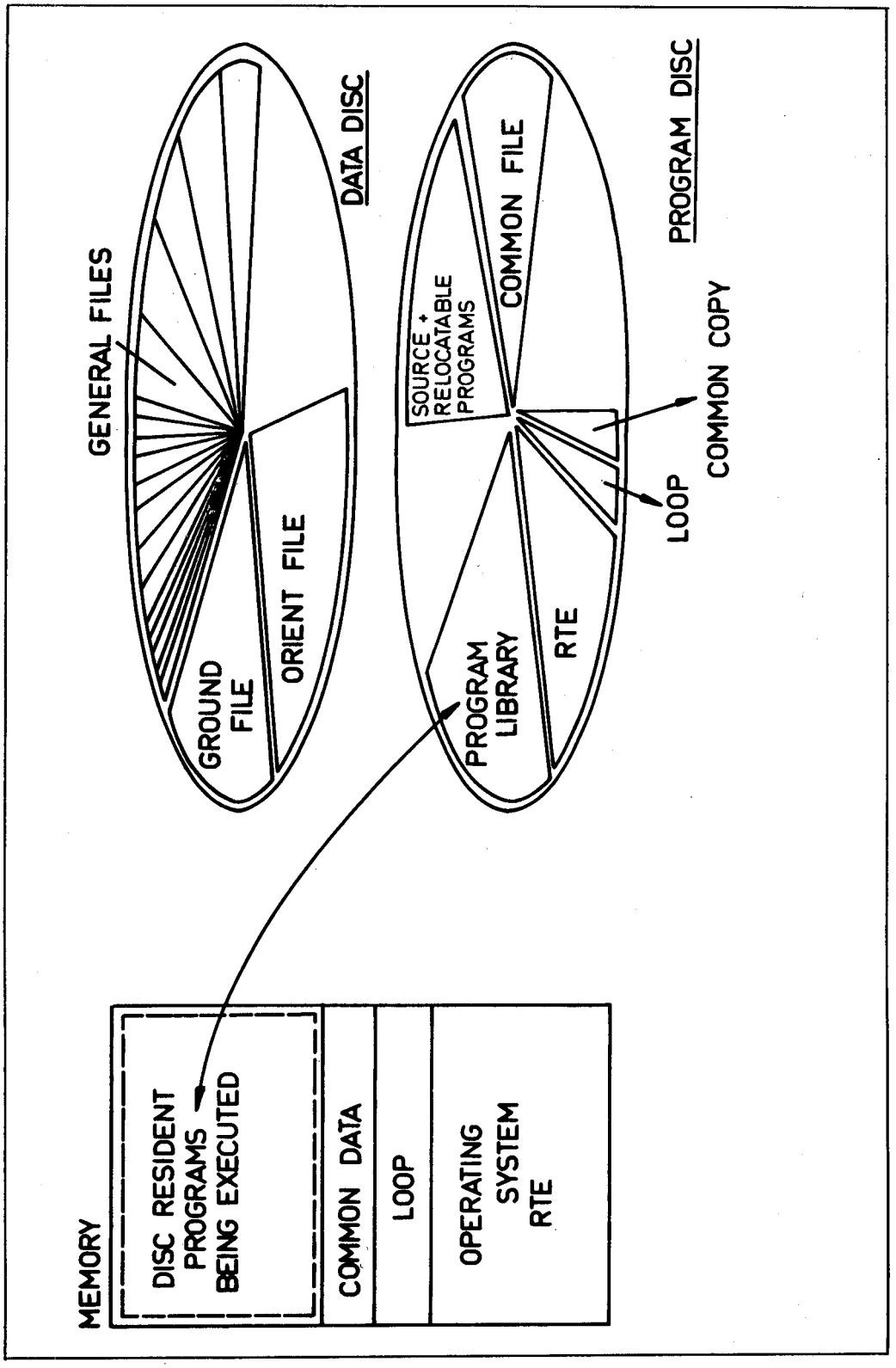

Fig. 11: Memory occupancy in computer of C-100 PLANICOMP.

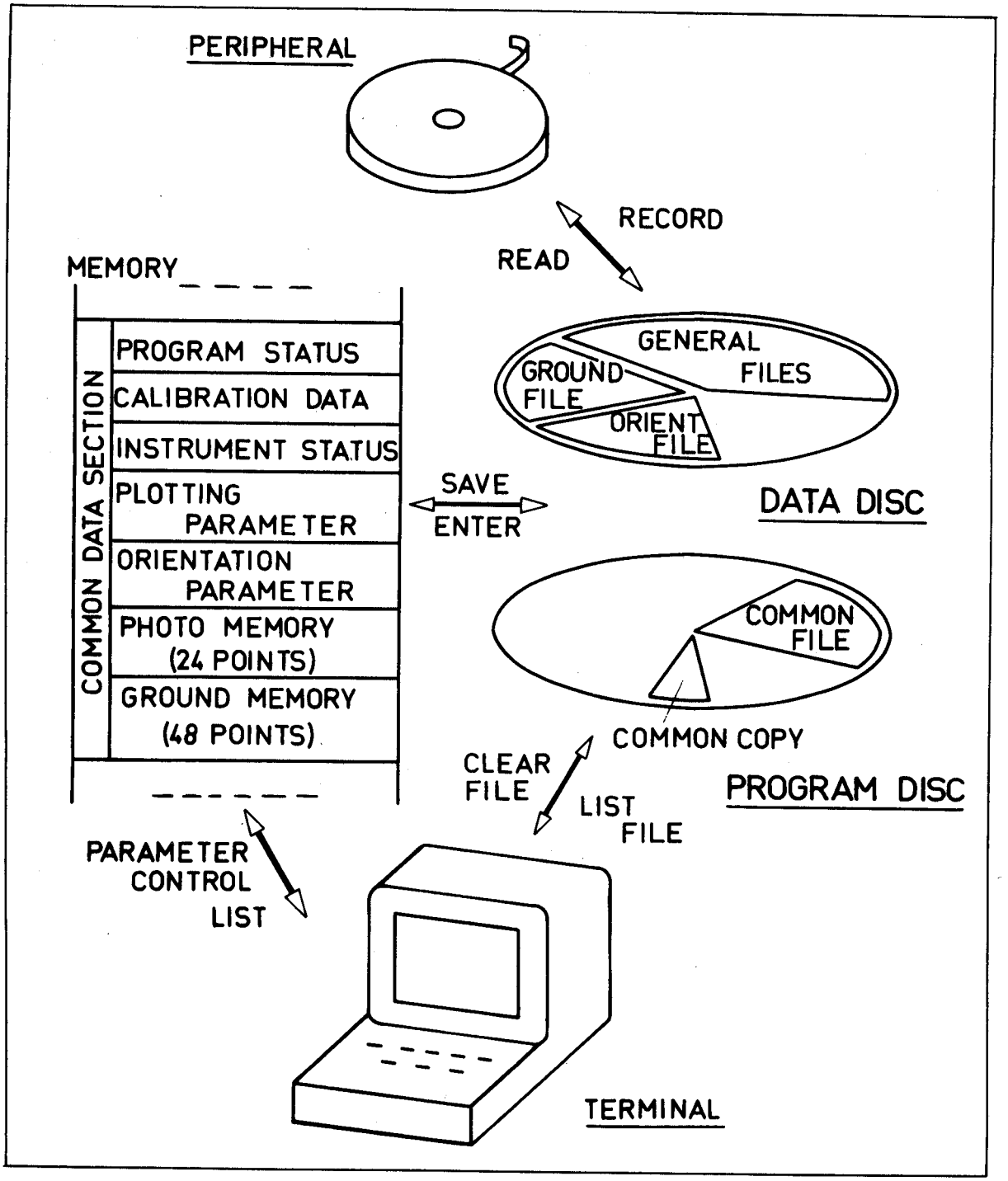

Fig. 12: File structure and data transfer.

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Konfiguration und Leistungsmerkmale des Analytischen Stereoauswertesystems PLANICOMP C-100

Zusammenfassung

Das analytische Stereoauswertesystem PLANICOMP C-100 von CARL ZEISS, Oberkochen, wird hinsichtlich Aufbau, Programmstruktur und Leistung vorgestellt. Bestehend aus optisch-mechanischem Grundgerät, photogrammetrischem Bedienungsfeld, Steuereinheit, Rechner, Rechner-Terminal als Fernschreiber oder als Bildschirm, Rechner-Peripherie und Zeichentisch, gewährt C-100 in Verbindung mit ca. 75 vorhandenen Anwendungsprogrammen eine Vielzahl von Vorteilen gegenüber Analoggeräten: schnelle und objektive, ausgleichende Orientierung mit Ausgabe der Restfehler; Einzel- und Inkrementalregistrierung mit vielseitigen Möglichkeiten hinsichtlich der Inkremente, der Meßanordnung und der Ausgabeformate; Aerotriangulation mit unmittelbarer Datenkontrolle bei der Messung und spätere Gesamtausgleichung im Gerät ohne Datentransfer; Berechnung geometrischer Sekundär-Größen wie Schwerpunkte, Distanzen, Längen, Winkeln, Flächen, Rauminhalte; rechnergestütze graphische Auswertung (on line) durch Zeichnen von Geraden und geglätteten Kurven, ergänzendes Zeichnen, das Auftragen von Symbolen, Punktnummern, Höhenwerten, Namen sowie vollautomatisches Auftragen von Gittern, Punktfeldern, Vektoren. Mit einem größeren Analogsystemen vergleichbaren Kostenaufwand ist damit ein "photogrammetrisches Auswertezentrum" verfügbar, das über die beschriebenen Möglichkeiten hinaus auf zukünftige Erweiterungen vorbereitet ist.

Structure et caractéristiques du système de stéréorestitution analytique PLANICOMP C-100

Résumé

Le système de stéréorestitution analytique PLANICOMP C-100 de CARL ZEISS, Oberkochen fait l'objet de l'exposé qui examine sa configuration, son software et ses performances. Le PLANICOMP C-100 se compose d'une unité de base optique-mécanique, d'un panneau de manoeuvre photogrammétrique, d'une unité de commande, d'un calculateur, d'un terminal (téléimprimeur ou écran de visualisation), d'appareils périphériques et d'une table traçante. En conjonction avec environ 75 programmes d'utilisateur, il offre de nombreux avantages par rapport aux appareils stéréorestituteurs analogiques:

- Orientation rapide, objective et compensatrice, avec sortie des erreurs résiduelles
- Enregistrement de points isolés et enregistrement incrémental avec différentes possibilités quant au choix des valeurs incrémentales, du montage de mesure et du format de sortie
- Aérotriangulation avec contrôle direct des données au cours de la mesure et compensation globale ultérieure dans l'appareil sans transfert des données
- Calcul de grandeurs géométriques secondaires, p.ex. valeurs moyennes, distances, longeurs, angles, surfaces, volumes
- Restitution graphique assistée par ordinateur en opération "on-line" (tracé de droites et de courbes rectifiées, tracés complémentaires, report de symboles, de numéros de points, de valeurs altimétriques, de noms
- Tracé entièrement automatique de lignes de quadrillage, de semis de points et de vecteurs.

Avec des frais qui n'excèdent pas ceux d'un appareil restituteur analogique à grand rendement, le système PLANICOMP C-100 constitue un "centre de restitution photogrammétrique" qui, en plus des performances décrites, admet sans difficultés des extensions ultérieures.

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Configuración y características de rendimento del sistema analítico de estereorrestitución PLANICOMP C 100

Resumen

Se presenta el sistema analítico de estereorrestitución PLANICOMP C 100 de CARL ZEISS, Oberkochen, informando sobre su construcción, estructura de programas y rendimiento. El sistema se compone de un equipo básico ópticomecánico, un panel de mando fotogramétrico, una unidad de control, computadora en forma de teletipo o pantalla, equipos periféricos y mesa de dibujo. En combinación con unos 75 programas de usuario ya existentes, ofrece una multitud de ventajas respecto a los instrumentos analógicos: orientación compensadora rápida y objetiva con salida de los errores residuales; registro suelto e incremental con múltiples posibilidades respecto a incrementos, disposición de las mediciones y formatos de la salida; triangulación aérea con control directo de los datos durante la medición y ulterior compensación total en el instrumento sin transferencia de datos; cálculo de magnitudes secundarias geométricas, tales como centros de gravedad, distancias, longitudes, ángulos, superficies, volúmenes; restitución gráfica apoyada en computadora (on line) mediante el trazado de rectas y curvas aplanadas, el dibujo complementario, el dibujo de símbolos, números de punto, cotas, nombres y el dibujo automático de retículos, redes de puntos, vectores. Así se dispone de un "centro de restitución fotogramétrico" que está preparado para futuras ampliaciones además de las posibilidades descritas y cuyos costos son comparables a los de un sistema analógico mayor.

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