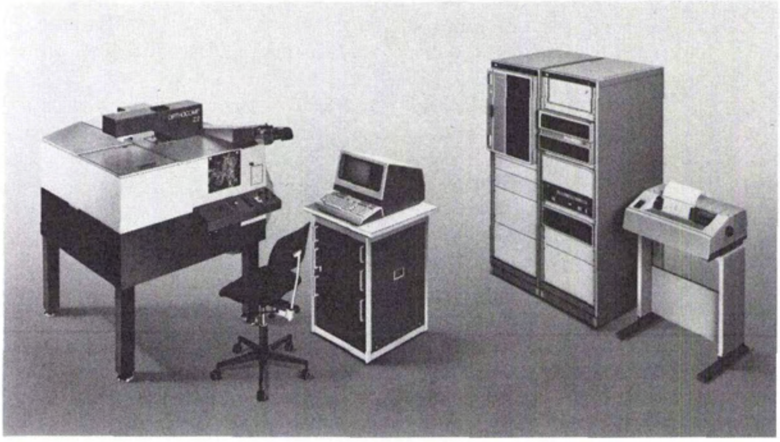

FRONTISPIECE. View of the Z-2 ORTHOCOMP. Left, The projector and the cabinet with the control electronics and the video terminal for the computer. Right, the HP-1000 minicomputer with tape drive and printer.

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Z-2 ORTHOCOMP, The New High Performance Orthophoto Equipment from Zeiss

Under computer control, the Z-2 ORTHOCOMP performs differential rectification of black-and-white and color material, of high oblique frame and panoramic as well as conventional frame photographs, utilizing height information in any arbitrary arrangement.

(Abstract on next page)

INTRODUCTION

HAVING A LONG and successful tradition both in manufacturing optical orthoprojectors (GZ-1 Orthoprojector, Ortho-3-Projector) and in orthophoto consulting (Hobbie, 1974) and with a widely accepted know-how in the analytical plotter field (C-100 PLANICOMP), Carl Zeiss Oberkochen introduced the Z-2 Analytical Orthoprojector at the 14th ISP-Congress in July 1980 in Hamburg (Faust, 1980). The first instrument delivery took place in January 1981. Since then the Z-2 ORTHOCOMP is being used worldwide in production environment; production rates of at least eight orthophotos (40 by 40 cm, hilly terrain) per shift are achieved by several users. This rate is based on the usual procedure which includes preparation of all necessary input, loading of photo and film, orientation, scanning, as well as printing of sheet grid and text annotations.

This paper deals with the technical concept of the *analytical* orthoprojector Z-2 ORTHOCOMP. The essence of being "analytical" rather than "digital" is the capability of accepting *any* form of digital elevation information (different profile pattern, contours, break lines, spot heights) and directly compute the necessary control data for scanning instead of using specially preprocessed

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profiles. Elevation data in the form of parallel profiles (not necessarily equidistant) can be used directly to derive control profiles for scanning; other forms of data have first to be converted to parallel profiles using the DTM interpolation program HIFI-P. Profiles can even be input in an arbitrary model system. These will be transformed into the ground system by a similarity transformation to a set of reference points.

Using these data, the system generates orthophotos by so-called differential rectification, linearly correcting for slope between profiles (first order rectification). The overall accuracy of the Z-2 product is better than 9 micrometres RMS error for a square grid (constant elevation) and better than 48 micrometres for a grid model (polyeder input image) simulating terrain with elevation differences of 40 percent of the flying height (being "photographed" with 150-mm focal distance), both values referring to a 1:1 orthophoto.

ABSTRACT: *With the Z-2 ORTHOCOMP, Zeiss introduced a new analytical orthoprojector, which allows high quality first order differential rectification (cross slope correction) of black-and-white and color material.*

The main hardware components are the output drum for film sheets of up to 1 by 1 m, the high power optical zoom for continuous 0.4 to 12 × enlargements, the Dove prism for 360° image rotation, the photo carrier (optional 9 by 18 inch), and the zoom-equipped illumination system, all servo controlled and interfaced to an HP-1000 minicomputer.

With a scanning speed of up to 50 mm/sec and a step width of up to 16 mm, the scanning of a typical 500 by 500-mm orthophoto will be completed within 7 minutes.

The powerful software package supports fast data entry and orientation of the photo to be rectified, density measurements, scanning, and additional symbol printing and text annotation. The system can even handle unusual input such as high oblique frame or panoramic photographs. Terrain profiles from any source are used for scan control. Profile spacing does not need to match the width of the scanning slit, and point interval on profiles may vary. Using the optional HIFI program (Ebner), control profiles can be derived from an arbitrary arrangement of height information input. This DTM interpolation program can be run as a background job on the Z-2 computer.

In the following paragraphs the components of the Z-2 system (Frontispiece) are described: The projector as the opto-mechanical basic equipment, the control electronics, the computer with video terminal, and the software. Several modules for these components were adopted from the proven C-100 PLANICOMP analytical stereoplotter.

THE PROJECTOR

Figure 1 shows the principle of the opto-mechanical design. The film to be exposed is fixed on a drum. In this way a clear definition of the position of the film surface is achieved even with large film frames (up to 1050 by 1040 mm). This drum is securely built into the projector with high-precision pivots. During projection of the orthophoto, it is rotated at a constant speed (selectable in stages 5, 10, 20, 30, 40, and 50 mm/s at the film surface). Just above the drum there is a scanning head carrier with an arrangement of four scanning slits which can be introduced alternatively into the path of the exposing light beam (standard slit width of 0.2 mm with lengths of 2, 4, 8, and 16 mm). The scanning head carrier with the scanning slit disk is driven by a spindle which moves the head one strip width after exposure of each strip.

The photograph to be rectified (diapositive or negative on film or glass plate, black and white or color) is placed on the photo carrier which can be driven in x and y directions by two spindles. The frame size in the standard version is 9 by 9 inches, but 9 by 18 inches is also available as an option.

The photograph is projected on an intermediate image plane with a zoom lens and onto the scanning slit using additional optical elements. A switch-over system (plane mirror/double reversing mirror) is located in front of the intermediate image plane for normal or for reversed image exposure. A Dove prism is arranged behind the intermediate plane for rotating the image. The most significant optical component is the zoom system for the continuous variation of magnification between 0.4× and about 12×, achieving a magnification factor of about 30. This zoom system is characterized by its mechanically very simple and therefore trouble-free design. In consists of four fixed lens groups and three lens groups which are arranged on a single carrier and moved as a whole. Typical photographic resolution values referred to photo scale are

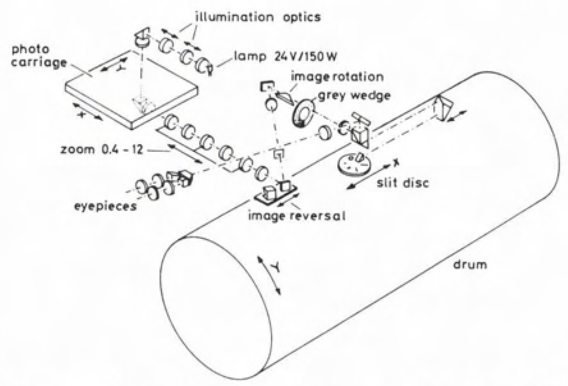

FIG. 1. Diagram of the optics in the Z-2 ORTHOCOMP.

zoom magnification	1×	2×	3×	6×
resolution (lp/mm)	26	48	79	≥100

These are average values for zoom settings within the range of the mean magnification usually employed in orthophoto production.

The optical system has an exit pupil which is constant in terms of position and size so that the irradiance of the film is independent of the magnification. Two movable optical parts in the illumination optics serve to ensure that in all zoom positions the filament of the 24 volt/150 watt halogen lamp is always projected into the exit pupil. This results in a high degree of irradiance of the film so that even less sensitive reproduction films can be exposed at a speed of 50 mm/s. The rotatable grey wedge is also located close to the exit pupil. With this the brightness can be adjusted to the sensitivity of the film, the average density of image, and the selected drum speed.

The binocular is used for direct observation of the scanning slit plane through a beam splitter. Instead of the scanning slit, a reflecting measuring mark disk is brought into the taking beam for orientation of the image. The measuring mark of 0.04-mm diameter is viewed with 5× magnification. The photo sensor with which the optical density of the photograph is measured is not shown in Figure 1.

THE CONTROL ELECTRONICS

The electronic components for controlling the projector are housed in three modules in a small cabinet with a table surface on which the computer terminal can be placed (Frontispiece). The control electronics include numerical and logic modules which enable data exchange with the computer, as well as amplifiers for servo drives in the projector. The control electronics also support the operating panel which is situated on the projector beneath the eyepiece.

Eight computer-controlled servo drives for drum (y_0), scanning slit position (x_0), photo carrier (x_c, y_c), zoom, Dove prism, and two lens groups in the illumination optics, are controlled according to the C-100 PLANICOMP principle, with its proven performance and reliability. The spindle drive is implemented with a motor/tacho unit. The positions achieved are derived from pulse transmitters which are coupled directly to the spindles. The resolutions of the pulse transmitters are 1 micrometre for the photo carrier and scanning carrier, 2.5 micrometres for the drum (measured at the drum circumference), 8 micrometres for zoom and illumination optics, and 0.25 mrad for the Dove prism. Other servo drives, which are not controlled by the computer, move the scanning disk for changing the scanning slits and the position of the grey wedge. The operating panel (Figure 2) has six program buttons to start the programs for parameter input, orientation, density measurement, orthophoto scanning, symbol printing, and log printout. Two buttons, CONTINUE and REPEAT, serve to control execution of the programs. Rotary buttons adjust the brightness (grey wedge positioning), the scanning slit, and the film speed. A joy stick permits sensitive positioning of the photo carrier during orientation and density measurements. Measured density is digitally displayed on the operating panel.

THE COMPUTER

The minicomputer system, a Hewlett-Packard HP-1000, which has proved itself with the C-100 PLANICOMP, was selected for controlling the Z-2 ORTHOCOMP. The minimum hardware configuration requires a 128K word (16 bit) memory, a disk drive with 20M bytes or more, and a video terminal.

A magnetic tape drive is usually connected to provide additional flexibility for entering elevation data. The exchangeable cartridges of the disk drive or a data communication interface to another computer can be used as alternative input media. One can expand the computer configuration if further tasks should be run on the system parallel to orthophoto production. Typical tasks are batch processing such as HIFI-P (Ebner *et al.*, 1980) as well as interactive programs, e.g., parameter editing, data acquisition, or program development.

BASIC SOFTWARE

The basic software consists of the RTE Operating System from Hewlett Packard including utility programs such as editor, compiler, loader, and the ORTHOCOMP service programs. The service programs support different tasks and are called by dedicated keys on the orthoprojector operating panel. These service programs are

PARAMETER

This is a program for checking and changing parameters related to the aerial camera, orientation

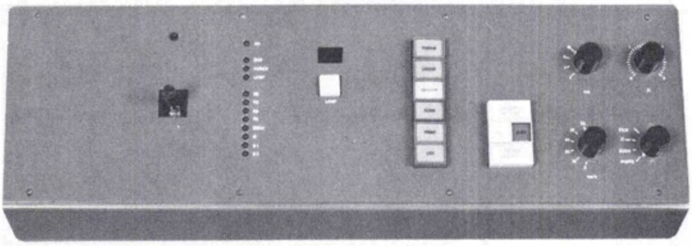

FIG. 2. Control panel of the Z-2 ORTHOCOMP.

control, orthophoto data, scan and point control, and log information (e.g., focal length, control points for orientation, orthophoto scale, and sheet corner coordinates). The operator is guided through the program from the screen. Data which have not changed since the last rectification can be confirmed by pressing a single key at the terminal. Data which concern the control points and the profiles, as well as precomputed orientation data, can also be read from tape.

ORIENT

This is a program for interior and exterior orientation (space resection) of the input photograph. At least two fiducial marks are needed for interior orientation. A minimum of three and a maximum of ten control points can be used for absolute orientation. The attitude and the station parameters of the input photograph are calculated from the ground coordinates of the control points and their measured photo coordinates. In case of poor results the orientation procedure may be easily repeated. If the orientation parameters were already available from an analytical stereoplotter, from block adjustment, or from a previous run, only interior orientation is required.

DENSITY

This is a program for measuring the optical density at different areas of the input photograph. Setting of the measuring area in question is done with the joy stick. The optical density can be read on a double figure digital display. After completion of the measurements, the largest and the smallest density value and the mean of all measured values are displayed on the screen. In a special mode this program also supports the use of the Z-2 ORTHOCOMP as a monocomparator.

SCAN

This is the program for projection of the orthophoto. Projection onto the film is made by scanning within the boundaries defined by the given sheet corners and a selected runover. (If no sheet corners have been entered, then the area covered by profiles will be projected.) The program implements a first-order differential rectification with model approximation by secants. With this method adjacent strips are, in principle, completely free of mismatch. Residual errors due to slack, elastic deformations, and electronic time constants are less than 0.1 mm in the orthophoto, except for the acceleration zones of about 5 mm added at the strip ends. These acceleration zones are automatically defined beyond the sheet corners as function of the chosen scanning speed.

The light intensity of the optical system is more than adequate for blue sensitive reproduction film when using a 0.2-mm slit width and 50-mm scanning speed. For more sensitive films, or for lower scanning speeds, the light intensity can be reduced using the grey wedge by a factor exceeding 1000.

The accuracy of the scanner thrust is so high that strip overlaps or gaps can be kept under 3 micrometres and are therefore almost invisible.

The SCAN program accepts profiles within any rectangular coordinate system as long as a reference to the ground, or to the photo to be rectified, is given. Using this primary set of profiles, the program interpolates a new set of equidistant control profiles which match the scanning slit length. This interpolation of control profiles allows the use of primary profiles of almost any pattern.

The primary profile data may be arranged in a meander pattern (successive profiles running back and forth) or in a comb pattern (with all profiles running in the same direction). The profile interval does not need to be constant, and point intervals within the primary profiles may vary. A minimum of two primary profiles, each consisting of two points, will be accepted by the program.

The SCAN program handles conventional central-perspective and panoramic images with any tilt.

PRINT

This is a program for projecting alphanumeric characters and a selection of cartographic symbols onto the orthophoto. A characters and symbols matrix on the photo carrier is used for this purpose. For example, symbols for the sheet corners or for the control points can be marked onto the orthophoto, the sheet name can be placed on the edge, or names of localities can be projected onto

FIG. 3. Orthophoto with automatic print of marginal information generated with the Zeiss ORTHOCOMP (3:5 reproduction).

the orthophoto. The angular positioning of the characters is optional, and size can be selected between 1.5 mm and 7 mm. These operations are controlled by prism rotation and by zoom setting. This program proved to be an important tool. It is employed by all Z2 users, at least for printing sheet corner symbols and for marginal annotation to facilitate map identification (see, for example, Figure 3).

LIST

The LIST program produces a standard listing (job report) with details such as operator name, task details, number of the rectified photograph, number of the control points used during orientation and residual errors after adjustment, speed and slit widths for projection, time duration for the projection, etc.

These programs are normally worked through in the sequence given here. The orthoprojector can be operated in daylight. The room need only be darkened for initial insertion and subsequent removal of the film. The film can be inserted immediately before starting the SCAN program, or earlier. One can, for example, put in the film for the next orthophoto after finishing a previous run. Several small orthophotos can be projected onto one large film.

Optional Software

Particular emphasis has been placed on the development of a self-sufficient system which can be employed as much as is possible independently of preliminary work sequences. As a consequence, the ORTHOCOMP is not limited to just the reading of photo coordinates of the scanning traces as in digitally controlled orthoprojectors, but is made open for accepting parallel terrain profiles. For many projects it is necessary to derive profiles from digitized contours or from a height data base or even to "rotate" the profiles if their direction does not match the required scanning direction. These transformations are performed by the optional program HIFI-P. This program allows derivation of profiles from elevations of arbitrarely distributed points. Another optional program, HIFI-C, uses the output of HIFI-P to compute and to control the drawing of contour lines on the digital tracing table DZ-7. Both programs are based on the finite elements interpolation method (Ebner *et al.*, 1980). They were tailored for the HP-1000 for use with the ORTHOCOMP and with the PLANICOMP. The minimum configuration for running HIFI-P in parallel to scanning in the ORTHOCOMP is 192K words of memory.

Other optional software performs special tasks such as stereomate-production and optical transformation between different types of projection.

Conclusion

The Z-2 ORTHOCOMP analytical orthoprojector allows fast and efficient orthophoto mapping through high quality optical means. With the largely computer supported preparation steps, and with the maximum output speed of up to 55 mm/s and maximum slit width of 16 mm, a complete orthophoto cycle requires between 20 and 60 minutes depending on sheet size; thus, the ORTHOCOMP is very well suited for high production rates.

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3rd Australasian Remote Sensing Conference Landsat 84

Surfers Paradise, Australia 21-25 May 1984

This conference is being coordinated by the Queensland Remote Sensing Committee with the assistance of the Department of Mapping and Surveying. The program will include

- Invited overseas speakers to deliver keynote papers
- Papers presenting topics of significant research or application
- Poster Papers
- An Exposition
- Workshops

"Landsat 84" will immediately follow the International Rangelands Conference being held in Adelaide, thus allowing overseas visitors with related interests the opportunity to attend both conferences.

For further information please contact

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Landsat 84 Conference Committee
P.O. Box 234
Brisbane, North Quay, Q. 4000
Australia
Tele. (07) 224-6577

CALL FOR ABSTRACTS

9th Aerial Color Workshop

With emphasis on Orchards, Groves, Vineyards and Tree Crop Analysis

The 9th Aerial Color Photography Workshop has been scheduled for November 15, 16 and 17, 1983 in Lake Alfred, Florida. The Agriculture Research and Education Center, Institute of Food and Agricultural Sciences of the University of Florida will host the meeting which is sponsored by the American Society of Photogrammetry and presented by the Florida Region.

Abstracts should be submitted to the technical program committee by June 30, 1983. A one-page abstract of less than 250 words should include the title of the paper, author(s) name(s), affiliation and address. Emphasis should be put on aerial color photography uses in tree crop inventory, damage assessment and new developments. The authors of papers accepted for presentation will be notified by the 15th of August. Camera-ready copy of accepted papers should be received by September 15 in order to appear in the proceedings which will be available at the symposium.

Send abstracts to:

George Edwards
AREC/LA 700 Experiment Station Road
Lake Alfred, Florida 33850