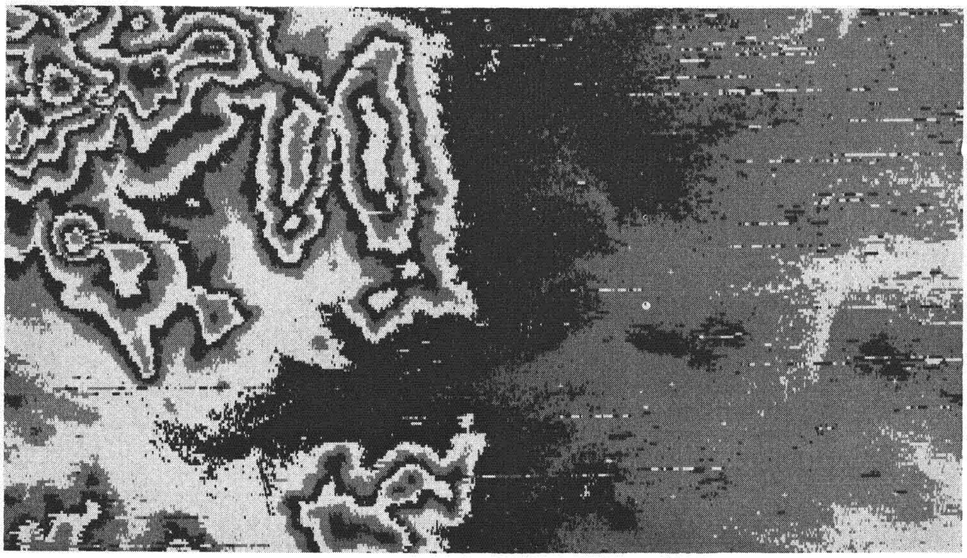

FRONTISPIECE. Drop-line contours compiled by the UNAMACE. (See text page 276.)

EDWARD F. BURZYNSKI†
U. S. Army Engineer GIMRADA
Fort Belvoir, Virginia

UNAMACE Tests

The Universal Automatic Map Compilation Equipment, now shown to be practical, may evolve into commercial instruments.

(*Abstract on page 275*)

INTRODUCTION

THE Universal Automatic Map Compilation Equipment known as the "UNAMACE," developed by GIMRADA, was recently successfully tested for meeting contractually stated requirements. The equipment and its operating principles were described by Bertram in 1965.* Testing was conducted on two sets of equipment; one located at GIMRADA and the other at the Army Map Service. These tests and their results are the topics of this article.

The equipment is the product of an intensive research program to develop an automatic system for the rapid compilation of orthophoto military maps and for their reproduction for use by ground forces in the field. The universality of the equipment stems from its use as a precision stereocomparator and as a compilation instrument capable of operating with various types of photography covering a wide range of focal lengths and flying heights. In addition, the computer can be utilized to generate the camera station and orientation necessary for the compilation operation from the comparator measurements, known camera characteristics, and known geodetic control.

† Presented at the Annual Convention of the American Society of Photogrammetry, Washington, D. C., March 1966 under the title, "Universal Automatic Map Compilation Equipment."

* Bertram, S., The Universal Automatic Map Compilation Equipment, *Photogrammetric Engineering*, Vol. 31, No. 2, March 1965.

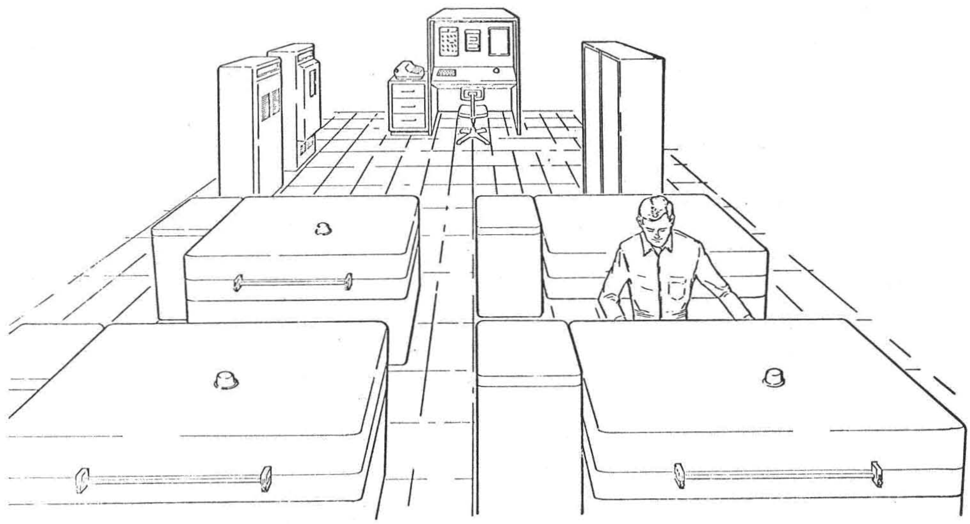

FIG. 1. Arrangement of the UNAMACE equipment complex.

The equipment is intended to produce high quality orthophotos and altitude charts from a variety of photographic inputs, including convergent frame or panoramic pairs up to 9-by-18-inch formats.

These instruments rapidly and accurately determine terrain altitudes by locating and measuring the position of images of corresponding areas in the common field of photographs taken from different camera positions. They also produce orthophotos (new photographs) to a precisely defined scale in which distortions caused by variations in camera altitude, relief distortion, and other known distortions in the original photographs have been removed. Orthophotos, from contiguous stereo pairs, may be joined to form mosaics covering a large area. The altitude contours derived from the height measurement can then be added, along with any desired annotations, to form an accurate "orthophotomap" of the area of interest.

System Description

Figure 1 shows the layout of the UNAMACE equipment complex. The UNAMACE consists, physically, of four identical compilation/comparator tables with a small rack of associated electronics, a control console, a computer with associated controller, and a double rack of control electronics. The tables may be used for scanning or printing operations. The console contains a stereoviewer and reference viewer among its components. The stereoviewer permits convenient setup of the equipment and provides a "window" for monitoring system operation. The reference viewer supplements the monitoring operation of the stereoviewer by providing a larger field of view to the operator. The double electronics rack contains the electronics for scanning, correlation and for tying the computer into the rest of the system. The controller unit acts as the communications element between the computer and the rest of the system.

Tests Conducted

The tests performed on the UNAMACE included unit acceptance tests, performance tests, and reliability tests. The tests were conducted according to an approved test plan for the equipment. Preliminary testing was conducted at the contractor's plant with final acceptance testing at the GIMRADA and Army Map Service site installations. As a major compilation exercise, a group of 39 vertical frame compilations were made during preliminary acceptance testing. These compilations covered two 15-minute quadrangles. The output scale of this exercise was equal to the nominal scale of the input diapositives. The average compilation times for 9- by 4.5-inch orthophotos for this project was approximately 50 minutes. The input data for the quadrangle exercise were obtained from a simultaneous block triangulation and adjustment technique developed by GIMRADA in 1962. (Figure 2.)

Test Results

During the tests run on the UNAMACE, the tables were individually checked for accuracy for comparator operations, and over

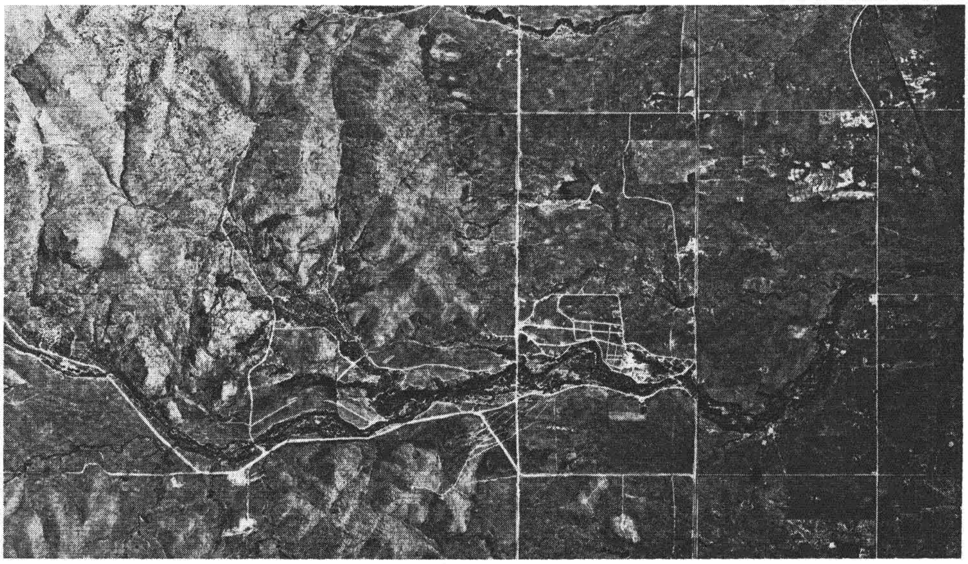

FIG. 2. Orthophoto output of the UNAMACE.

100 stereo pairs of diapositives were compiled. The compilations were made from vertical frame, 25-degree convergent frame and convergent panoramic photography. Additionally, comparator measurements were made on diapositives to determine acceptability of self-generated orientation data. A 9- by 18-inch precision grid was used for the comparator accuracy tests.

Tests performed on the stereoviewer revealed that the unit provided imagery of good quality, and satisfactory stereo images were produced for monitoring system operation. Image recovery capability of the unit was verified through parallax readings, wherein no point read exceeded an error of two microns.

The reference viewer was tested for correspondence of the illuminated area on a photograph, to that of an area being scanned on a reference table. The correspondence accuracy attained was ±0.5 millimeters. As only an approximate accuracy requirement was written into the equipment specification, the increase in accuracy obtained is a dividend.

Input parameters that produced successful compilations included photography of 6- and 12-inch focal lengths, 25-degree convergent photography, externally and self-generated orientation data, camera calibration data that included photographic and lens distortions values, and the product parameters of output scale, contour interval, symbols, control locations, and grid intersections. The performance of the items associated with these areas of interest offered no problems during the testing operations.

The general computer programs written for these equipments were adequate for the materials tested. Satisfactory compilations resulted from the operational frame and operational panoramic programs. The programs also produced data applicable to resection/compilation operations, from the comparator

ABSTRACT: *The Universal Automatic Map Compilation Equipment automatically obtains terrain altitude data from input aerial photographs and outputs orthographically correct photographs as a step in the map production process. This equipment, a combination compilation/comparator instrument, was recently successfully tested in a production environment, for meeting contractually stated requirements. The results of this testing indicate a definite breakthrough in automatic mapping. Instrument and correlation accuracies of 4 microns* RMSE, *printout accuracies of 30 microns* RMSE, *high resolution, and high scanning speeds attest to the significant improvement in the art of map compilation.*

mode, as well as acceptable data from a decimal-to-binary conversion program. Areas of poor correlation, judged as difficult to handle by the correlation process, were adequately handled by an adverse area routine, and computer input/output functions were tested successfully with a computer diagnostic routine. The comparator/compilation programs are highly flexible, providing for convenient re-entry points for restarting operations at intermediate levels.

Tests of the orthophoto output resolution utilized a standard high contrast USAF Resolution Test Target. Scan and print operations using various combinations of tables for scanning and printing resulted in a maximum of 45 lines/mm and a minimum of 36 lines/mm in the outputs. The average resolution for approximately 20 runs was 40 lines/mm. As a further test, analysis of 4× enlargements of orthophotos, which were, produced from the model compilations, showed no loss of imagery, attesting to the high resolution capability of the UNAMACE.

one of the compilations involving the 9- by 9-inch output size, the X-printout increment was doubled, resulting in a compilation time of 45 minutes, or half the time needed for compilations utilizing the normal printout increment width.

The accuracy tests on the equipment were concerned with C-factor determination and with comparator, correlation, and printout accuracies. Tests for the C-factor determination were made with real data and fictitious data. The former was intended to provide a test with real data and still eliminate the minor photographic anomalies not yet definable. The intent of the fictitious model was to determine a theoretical instrument C-factor completely divorced from errors contributed by other sources. The real model achieved C-factors of 1,470 and 1,500. The fictitious model had values of 4,400 and 4,800. The C-factor values presented above are equivalent vertical values of a desired 5,000 C-factor with 30-degree convergent photography, flown at great heights, for

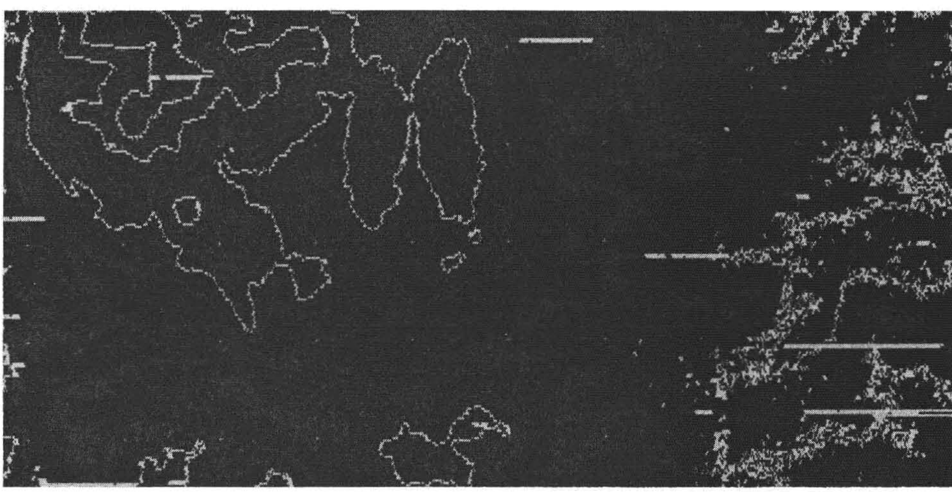

FIG. 3. Continuous-line contours compiled by the UNAMACE.

Contour compilations included drop-line data (Frontispiece) and directly printed continuous line contours (Figure 3). Selection of the drop-line or continuous line contour mode is accomplished by program tape.

Determination of equipment speed was made from the compilation times of a multitude of models that produced 9- by 4.5-, 9- by 9-, and 9- by 18-inch orthophotos. The average compilation time for the 9- by 4.5-inch orthophotos was 50 minutes. The 9- by 9-inch size averaged 86 minutes, and the 9- by 18-inch orthophoto averaged 170 minutes. In

which photography was not available. The calculated vertical equivalent of the desired 5,000 convergent C-factor is 1,240.

As a comparator an appropriate parameter is readily defined in terms of errors in measurements made on a precision grid plate. A total of 24 sets of measurements were made on the tables comprising the two equipments. A total of 55 points were measured in each set and a *RMSE** for each table axis determined. For the GIMRADA system, one out of eight

* Root Mean Square Error.

axes determinations exceeded the required four microns† *RMSE*. Five of the axes values were less than three microns *RMSE*. In the AMS system five axes exceeded the equipment requirement. However, only one axis greatly exceeded the specification and this by 1.6 microns. The incorporation of a linear scaling correction into the computer program will enable those tables in error to achieve the required tolerance.

The requirement for a correlation accuracy of four microns was verified by determining the automatic image recovery capability of the equipment, through automatic control of the correlation circuitry, and by making numerous parallax measurements on various points and recording the parallax differences. A total of 80 measurements were made in each system. The CPE‡ obtained from the data analysis of the GIMRADA instrument was calculated to be 2.4 microns. The AMS system returned 3.7 microns.

The printout accuracies were determined through the scan and print of a 9- by 18-inch precision grid with the system directed to the compilation program. A total of 45 grid intersections were scanned and an independent evaluation was made for each axis of the printout tables. The GIMRADA instrument calculated 11 microns *RMSE* for each table axis while the AMS system obtained 15 microns for the X-axis and 10 for the Y-axis. The above values are well within the 30-micron *RMSE* printout accuracy requirement.

A preliminary value of system reliability was obtained from a day-by-day log of system operation, including down time and failures for a period beginning 1 September through 8 December 1965. This preliminary mean time between failures (*MTBF*), the yardstick for reliability, was calculated to be 90 hours. The *MTBF* value arrived at fails to meet the stated requirement of 100 hours; however, the equipment operation is still in what may be termed the "shakedown phase," and the number of failures falls within a continue-to-test category. The final reliability of this equipment will be determined upon completion of engineer design tests now in progress.

Future Improvements

The orthopotos and altitude chart outputs from the UNAMACE will be very useful in map production work. The conversion of these to an acceptable map format will, however, require a great deal of manual labor, so the automation of the process is just started. Improvements to the UNAMACE, that are well within the state-of-the-art, can be expected to make the output more useful and to correspondingly reduce the operations requiring manual attention.

A magnetic tape capability has recently been added to the equipment to store the measured altitude data. This will make possible a smoothing of the data before the altitude chart is made. The addition of an appropriate alpha-numeric printout facility will permit the automatic printout of contour lines requiring a minimum of touch up.

Equipment and computer programs are being modified so that continuous grid lines can be output directly in place of the grid tics now being printed.

The availability of a computer with magnetic tape output, during preliminary operator examination of the photographs, should provide a step toward automatic color separation, a major cartographic operation. This may be accomplished by inputting interpretive commands into the data base for use later in the map production process.

Conclusions

The UNAMACE has demonstrated that automation in photogrammetry is practical. The equipment provides one step toward complete automation in the map-making process. It is to be expected that commercially feasible instruments will also evolve from this development.

† 1 micron (micrometer) $= 0.001$ mm. ≈ 0.00004 inch.

‡ Circular Probable Error.