extended time cycle between the missile test operation and the publication of the final reduced data. Under present operating conditions the time cycle for optical data reduction is in excess of 7 to 10 days. For the future, consideration is being given to a 6 hour ballistic camera reduction; this will be accomplished by plate processing and reading in the field, and the data transmitted to the computer center for reduction. Also being considered for the near future is a 72 hour CZR Fixed Camera reduction, which together with the 72 hour Azusa reduction will present an entire missile trajectory. The shortened Fixed Camera reduction will necessitate only a revision of current operating procedures such as ready availability of overtime man hours, immediate-upon-call computer utilization, and release of data in tabular and/or tape computer output form rather than in a finished report.

The problem of increasing the accuracy of the Fixed Camera and Cine-theodolite systems is within the capability of the existing state of the art. Mainly required is a re-evaluation of current operating conditions and the expenditure of a minimum in time, effort, and funds. It becomes the responsibility of the data user to establish realistic accuracy requirements based upon the needs of his particular systems, rather than upon the ability of the range to supply the reduced data. Then the justification exists for expending that which is necessary to increase the accuracy of the systems.

At this point, some thoughts will be expressed on the concept of Experimental Design in missile testing. A missile test launch is a complex experiment of an important and expensive nature. As such, it is imperative that as much information as possible be derived from each test operation. In order to obtain the desired trajectory data to as high a degree of accuracy as possible, it is necessary that consideration be given to the rigorous and complete design of the entire test experiment. This includes the thoughtful considerations of experts in the allied fields of Planning, Engineering, Instrumentation, Data Processing and Data Reduction. It is only by effecting coordination through the medium of meetings and conferences, sufficiently in advance of the missile operation, utilizing the experience and abilities of the specialists in the above mentioned fields, that the range user can be assured of obtaining his required data to the desired degree of accuracy.

*The Implementation of the Integrated Mapping System**

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(*Abstract is on following page*)

VIRTUALLY everyone connected with the operational phases of the photogrammetric processes as applied to cartography has had in his own plans, the application of an automatic process of matching images and thus obtaining automatic stereo plotting. Steps are being taken which will bring this into reality.

Camera and supporting equipments are reaching higher performance levels. As a source of error the camera is virtually no longer a problem. Lens distortions can be maintained at tolerably negligent levels, film and processing can be controlled. Instrumentation for the purposes herein described must, therefore, not destroy the accuracy contained in the diapositives from which it works.

A modification of the approach to the production of accurate orthophotoscopes, the development of which was explained by Russell K. Bean in 1955, provides the basis used in this instrumentation for the orthophotoscopic record.

The concept of contour delineation through the act of profiling, as revealed in the Decem-

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ber 1957 issue of PHOTOGRAMMETRIC ENGINEERING by Spooner and associates at Army Map Service, is brought to fruition in this instrumentation. This paper is (in part) a progress report based on the implementation of the principles proposed by the Army Map Service at that time. The merits of profile-scanning instead of contour-tracing for the purpose of hypsometry were convincingly treated by Messrs. Spooner, Dossi and Misulia. Benefits accruing to the operator, as regards time reduction and operator training, are evidently significant.

The three products of the Integrated Mapping System as conceived by the Army Map Service are:

1. Plotted Contour Information
2. Orthographically Positioned Photographic Detail, and
3. Stored Profile Data

The first product, of primary interest to all photogrammetrists in the cartographic field, must be contour information in a suitable form for the compilation of elevation data measurements to standard map accuracies.

The second, commonly known as the orthophotograph, can be used as a source of compilation of all planimetry in the operational phase of cartographic work. The imagery converted from a perspective view of the terrain, as it appears in the aerial photograph, to an orthographic view must be sharp, and contain enough detail for easy recognition and interpretation, and must meet the required standards for horizontal accuracy. Accurate orthographic proportions are not present in any case where the photographed terrain does not lie in one plane.

Tests made for comparison of the effects on the final model of profile-scanning, compared to conventional techniques of "chasing a contour" throughout the model, have shown the completeness of the profile technique to be superior. This was evidenced by the absence of isolated hill tops using the conventional methods. The improvement, of course, is the consequence of the fact that profiling compels the stereo operator to examine *all* parts of the model in detail.

The third product, a permanent record of the data used in the hypsometry, becomes a ready reference for use in a number of applications, as, for instance: map revisions; guiding the cutting arm of a terrain model cutting machine; and thirdly for data conversions such as vertical relief exaggeration or change of datum by utilizing a high speed electronic computer.

ABSTRACT: *The Integrated Mapping System is so implemented that from a stereoscopic exercise, through the act of profiling, several useful output products required in the production of topographic maps are obtained. These outputs are used to produce a topographic data compilation sheet, an orthophotographic exposure of the model area and to prepare a condensed record of the profiles in a form suitable for permanent storage.*

The system provides a stereo-operator with a memory-driven servo assist to drive the measuring mark of the stereo plotter up and down as the platen traverses the model area, by using the memory of the preceding profile as an approximation. The new profile can then be recorded on a temporary tape and can be used as an approximation for the next profile or to produce the aforementioned products.

Figure 1 *shows the three working components of the system.* It does not include the electronic-control system, which contains the temporary and permanent tape handlers, nor the operator's control console. The Stereoplotter, furnished by the government for this project, has been modified by the substitution of more powerful servo-motors to drive the X and Y arms of the coordinatograph, and the Z axis assembly.

The line drop-contour plotting table contains a similarly modified coordinatograph used to transport the line drop marking assembly.

The orthophotoscope unit also employs a modified coordinatograph which drives the orthophoto exposure unit. Exposure is obtained from a cathode ray tube operating from a closed circuit television system; the entire working system is enclosed in a light-tight housing for working convenience.

Figure 2 is a *close-up view* showing more detail *of the platen assembly* modifications. The

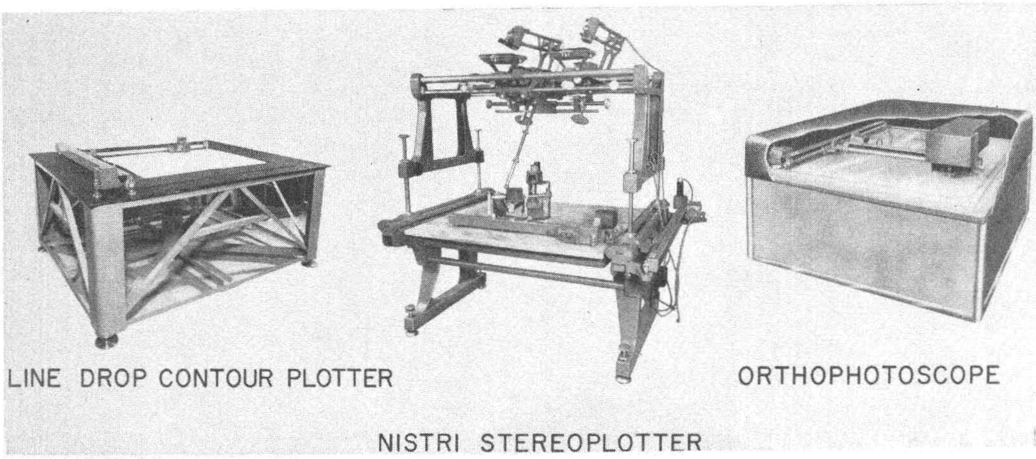

FIG. 1. Integrated map system.

"black box" at the left, adjacent to the circular platen, is the television camera pick-up tube, used to make the orthophoto. Together with the platen, it slides horizontally on a track which is driven vertically by the Z drive system. When the operator scans the profile the platen is in operating position. When the machine is recording the orthophoto, the camera tube is indexed horizontally into position. They both move up and down in the Z direction regardless of which is in operating position.

The *electronic control system* is illustrated in Figure 3. Three magnetic tape handlers can be seen at the left. Two of these are used for the control and recording of X, Y, and Z data on a temporary basis; the third is used to form the permanent tape record of the model area. At the upper right a television monitor screen can be seen. This is a monitor for the closed circuit television system and provides the operator assurance that the orthophoto, being formed in its light-tight enclosure, is receiving its video signal from the camera.

The remainder of the electronic control systrol system consists of the servo control for the coordinatograph arms and Z drive, the digital data handling circuitry for the acquisition, processing and control of the X, Y and Z information, and the several power supplies required by the system.

As a working system, Figure 4 shows the *tie-in between the several components*. Each of these units, the tape handlers, the stereoplotter, the line drop and orthophoto units, has only been touched on in describing the previous illustrations, and will be referred to again.

Through the act of profiling, the instrumentation produces all of the data necessary to produce topographic maps, master terrain models and allied products. In other words the instrumentation produces, as direct outputs, a permanent record of the profile data on magnetic tape, a contour-plot in the form of a line-drop compilation, and an accurate orthophoto.

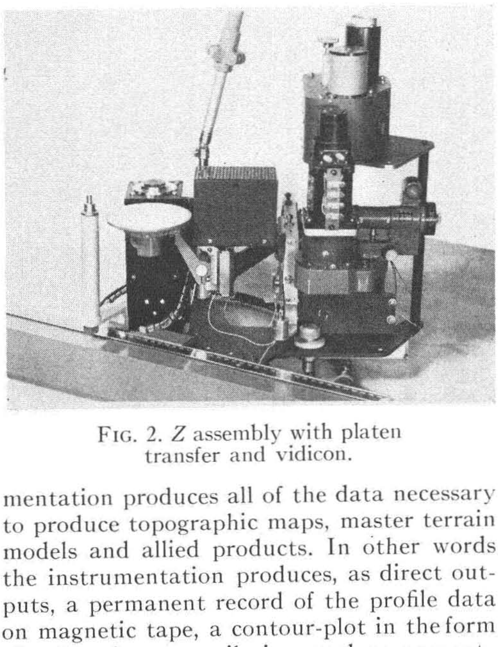

FIG. 2. Z assembly with platen transfer and vidicon.

Profiling is accomplished with greater speed and accuracy through the assistance of a memory system. A temporary record of the previous profile actually drives the floating mark, requiring the operator to provide merely corrective adjustment. The overriding adjustment made by the operator continually results in the formation of a new temporary record and may be repeatedly played back for review and correction.

The useful outputs, produced automatically by the machine, are made only when the operator is satisfied that the temporary record

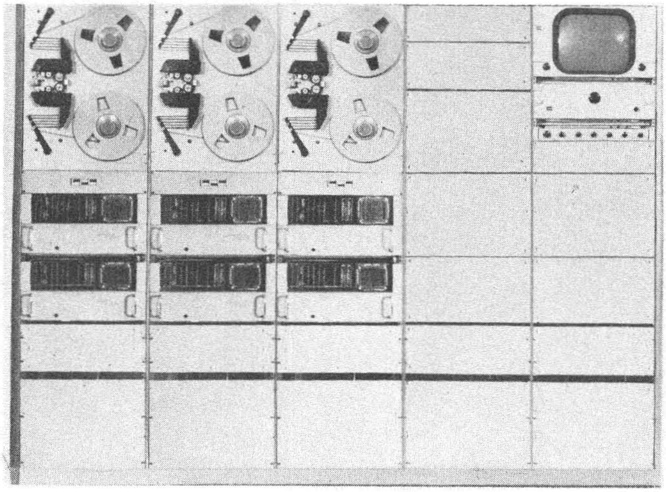

FIG. 3. Integrated map system, control system.

accurately contains the desired profile data.

Some of the significant data relative to the performance of the machine will now be presented, before continuing with a further explanation of its operation. The three tables have the same *X* and *Y* travel capabilities:

IN THE *X* DIRECTION:

a) The maximum travel is 800 mm. This pertains to the stereoplotter, the line-drop head and the orthophoto-exposure head.
b) Position is known and recorded to an accuracy of 1/10 mm.
c) The speed of travel is controllable by the operator from 0 to 20 mm. per second.

IN THE *Y* DIRECTION:

a) The maximum travel is 1,000 mm.
b) The *Y* increment value is adjustable in steps of 1/10 mm. up to a maximum increment of 12 mm., and is recorded to an accuracy of better than .025 mm.
c) The *Y* step-over time is a maximum of 72 seconds for a *Y* increment of 12 mm. (6/10 second per 1/10 mm. step)

IN THE *Z* DIRECTION OF THE STEREOPLOTTER

a) The maximum travel is 180 mm.
b) The actual *Z* value is recorded each 1/10 mm. of *X* travel to an accuracy of 1/10 mm.

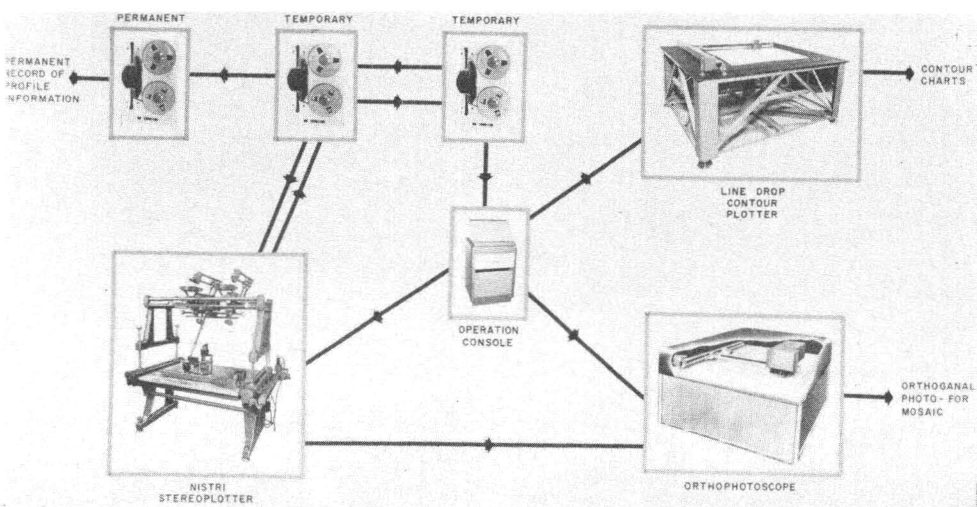

FIG. 4. Integrated map system.

c) The maximum speed of travel varies from 0 to 20 mm. per second.

The line-drop compilation has the following performance:

a) The *frequency* with which lines are dropped is adjustable to accommodate four contour level increments of 20 and 40 feet, 10 and 20 meters, and 9 model scales ranging from 1 to 3,600 to 1 to 10,000. These correspond to Z increments which range from 1 to 4 mm.
b) The *accuracy* of the dropped line end is 1/10 mm.
c) Line *dropping speed* is compatible with the scanning speeds in X and Z. Approximately 40 half contours can be recorded per second.

Lastly, the orthophoto system:

a) The *width* of the *exposed strip* in the Y direction is adjustable in 1/10 mm. steps, up to a maximum width of 12 mm.
b) *Six reduction ratios* ranging from 1 to 1, to 1 to 6 are provided.
c) The resolution capability of the orthophoto is 75 per cent of that obtained at the scanning platen of the stereoplotter.

Returning to the operation of the machine; profiling is done in the X direction (parallel to the flight direction). In the operating unit, the platen is driven at a *selectable* speed in the X direction (up to 20 mm. per second). While the operator "rides the profile," the machine will temporarily record the profile. Realizing that there is room for error in the first scan, the operator may, at the end of the scan, reverse direction and let the platen be positioned up and down in Z by the magnetic tape record just made. Should discrepancies occur, corrections can be made "on the spot" by an operator's over-ride control, resulting in a new recording of the entire profile.

Once satisfied with the profile, the operator may cause the machine to make the line-drop profile record sheet, an orthophotograph, and a permanent recording on magnetic tape, in any reasonable machine language for electronic computers. The language which has been selected for this machine is for use in the UNIVAC Model 1103A or 1105 computers.

During the operation on the second or adjacent profile, the temporarily storaged information from the previous profile is used to position the platen in Z, modified by the operator's override control to produce the recording of the new data. This means that only a single profile in the model need be worked with no previous knowledge of where the platen should be. Once accomplished, the memory aided mode of operation is fully effective. On a single profile, this information is available for refinement in the X direction or along the profile. On adjacent profiles, this information is available for the same type of refinement, but in the Y direction.

The memory aid profiling is done with an electronic analog to digital converter, capable of high resolution and an output of digital information at a rate of about 2,000 elevations per second. Since the rate of scanning, as presently called for, is a little less than one-inch-per-second, almost an infinite number of of readings of elevations are available to provide smooth operation.

As mentioned above, once the operator is satisfied with a profile, he may produce a contour sheet. This is done with the line dropping mechanism. Throughout the range of elevation (Z motion of the platen), there is provided a series of points corresponding to the selected contour intervals, which, while the profiling operation takes place, will operate the line-drop device.

This device will mark continuously from one elevation to the next, with alternate contour intervals left blank. This system has been further advanced from the compilation standpoint so that line identification will be provided by color coding. A compiler will be able to tell at a glance whether the slope is uphill or downhill, in any direction, and in any local area without reference to control points or drainage patterns.

As an example of this system, if the slope is uphill the sequence of color coding will be:

Red, Blank, Black, Blank, Green, Blank, Red, Blank, Black, etc.

A downhill slope would be just the reverse. In other words, if the sequence (not counting the blanks) goes from red to black or from black to green, then an uphill slope is indicated. A downhill slope would be indicated by a sequence of black to red or from green to black.

As the second product, which can be made concurrently, instrumentation will provide an ortho photo of the model area. This is provided by mounting on the platen a television camera which takes a picture of the local terrain (i.e., in the area of the floating mark). The actual exposure will be of an area of a few thousands of an inch in the X direction by the width of scan in the Y direction, equal to the

Y increment, and will be obtained from the projection of one of the diapositives of the stereo pair, with the red filter removed.

After being amplified by a remote video amplifier this signal is reproduced on a small Cathode Ray Tube which is mounted on a second electro coordinatograph. The remote CRT is mounted so as to make an exposure of all of the details in the photograph on to a flat sheet of photographic film. Proper photographic filtering will prevent the second photo of the model from being reproduced, or one light may be turned off since, during this operation, no stereoscopic viewing is required.

The CRT reproducer travels only in the X direction during a single profile (i.e., no Z motion is included in the making of the orthophotograph). Thus, a flat photographic exposure plane is used. True orthographic proportion is obtained by controlling the Z motion of the television camera pick-up tube from the tape recording. This technique, has the advantage of not having to raise and lower a large flat photographic sheet during the profiling operation as would be the case if the exposure slit and film were in the actual model space.

A second advantage is provided in the Integrated Mapping System concept in that the operator is given a chance to change his profile to a completely satisfactory one *before* making an exposure on the orthophotograph.

The third product is the provision for making a permanent recording of the model space. This can be done either concurrently with the line-drop contour chart and/or the orthophoto; or it may be made separately.

Operationally this does not cause any difficulty. It is expected that the three products—contouring, orthophoto and permanent recording—can be accomplished with only two scans of each profile (except the initial one).

Thus: Right to left on the initial scan will provide course data. Left to right will provide a check, or left to right—contouring, exposing and recording.

On subsequent scans, right to left will provide a check with minor corrections. Left to right—contouring, exposing and recording.

*Automation of the Aero Service/Haag-Streit Coordinate Plotter**

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ABSTRACT: *The purpose of this paper is to discuss the value of a directly coupled digital system of automation designed for the Coordinatograph on Static rather than Dynamic principles. Component parts such as the Flexowriter, Drive System, Programmer and Translators comprising the automated system, are explained relative to their applications to Photogrammetric requirements.*

BECAUSE of the rapid rate of technological advance in this country, it is difficult to predict what new developments will take place in manufacturing during the next ten years.

However, the predicted expansion of industry and population growth will surely lead to greater requirements for automation. This will be true in machining, press work and assembly operations of all kinds. It will include our own field, photogrammetry. The building block principle, in which machine tools are assembled from standard, interchangeable heads, bases and other components, will be generally accepted by industry and will make automation economically feasible.

Advances in our own field have demonstrated willingness of members of The American Society of Photgrammetry to meet the challenge of automation and to adapt some of the tooling and machining fields' techniques. With this in mind, more than two years ago, Aero Service Corporation embarked on a research and development project to produce a

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