Research Activities in the Field of Plotting Theory and Instruments

by S. A. Veres

Aero Service Corporation

Activities of the Aero Service Corporation has been devoted to the development and testing of the Laser-Airborne Profile Recorder and a new Airborne Magnetometer. The Laser-Airborne Profile is one of the most promising instruments for the photogrammetrist and is capable of achieving accuracy better than a foot. The Airborne Magnetometer has contributed to the exploration needs of petroleum and mineral industries since 1947. The new magnetometers based on the electro-optical properties of cesium vapor, rubidium vapor and helium, are capable of measuring the magnitude of the total magnetic field vector to a resolution of one hundredths of a gamma compared to the resolution of one gamma of previous instruments.

Bausch & Lomb Incorporated

Bausch & Lomb has been conducting the following projects in the field of plotting theory and instrumentation:

1. *Projection Plotter Lens Investigations.* The conventional Hypergon lens has been the standard lens for direct projection plotters for several decades. It has served well for angular field coverage up to 90°. Beyond that its limitations become aggravating. These are lack of resolution and strong vignetting at marginal regions of the projected field.

   Angular coverage of 120° has demanded a more complex lens system as already developed at B & L, which excels by almost doubling the resolution of the Hypergon lens and completely eliminating the internal vignetting which is detrimental to the marginal illumination of the projected field.

   A series of lens systems is presently being developed also in the 90° field which can replace the Hypergon. The new lenses are of the quadruplet category and will cover the range of small, medium and large scale mapping projectors.
2. *Plotter Concept Studies.* A general review of the direct projection system, the optomechanical and the purely mechanical system of mapping instrumentation is being undertaken to establish the present limitations and the prospects for further improvement. These are weighed against the analytical developments with particular emphasis on the future economical aspects of the instrumentation. These studies may result in completely new concepts leading to a sound economical solution.
3. *Special Plotter Applications.* New applications of photogrammetry to
   a. Dental research
   b. Electron-microscopy
   c. Underwater micro relief studies

   are being studied.
4. *Projected Scale Micrometer.* Two types of optical/mechanical measuring attachments have been developed for Bausch & Lomb's Stereo Zoom Microscope and Zoom 70 when used as a Stereo Zoom Microscope. The instruments permit the making of measurements on photographs to one one-hundred thousandths of a foot (.00001 foot), equivalent to approximately 3 microns. The instruments attach to the microscope pod. The measurements are independent of the viewing magnification, unaffected by any distortion in the viewing optics and do not require the placing of anything in contact with object or film being viewed.
5. *Optical/Electronic Absolute Measuring System.* Several investigations for the Bausch & Lomb DIG long-travel digital linear measuring system which utilizes glass scales for measuring to micron precision. At present it is being installed on a Mono-Comparator and is proposed for use on a coordinatograph type instrument for digitizing the stereo templet from projection plotters to permit adjustment on a computer rather than a templet lay-down.
6. *Variscale Stereo Point Marking Instrument.* The variscale Stereo Point Marking Instrument is currently under development at Bausch & Lomb for GIMRADA. It is intended for use in production mapping to provide for the identification and precision marking of con-

jugate image points on aerial photography. The VSPM is designed to handle a variety of format sizes (up to 9×18 inches) on film or diapositives, and scale differences up to 16:1.

Coarse conjugates of marked points, as well as other input data may be recorded by means of an IBM 526 card punch, which is interconnected.

The VSPM and its related components are designed for "clean room" operation.

Optical System—a binocular viewing system permits stereoscopic viewing at continuously variable magnification from 2× to 32×. Each half of the optical train may be zoomed independently for differential scale matching. Derotation prisms provide 360 degree image rotation in each optical path. Other features such as interpupillary distance adjustment, individual eyepiece focusing, *X-Y* phoria adjustment, parallax removal by means of a floating mark, and optical switching are included.

Scanning System—*X* and *Y* scan motions are controlled by a joystick for a continuous range of film speed from 25 mm./sec. for slowing to 1 micron/sec. for precise micro alignment.

Both photo stages may be driven individually or simultaneously. The illumination level on each photo stage is independently variable.

Measuring System—Coarse coordinate positions (least count 0.1 mm.) for each photograph are displayed visually on nixie readout tubes, located on the instrument panel, and may be recorded permanently on command by the operator to the card punch.

The readout system can be switched to the short range micro measurements mode to permit measurements of 1 micron increments which are also displayed visually. This system provides assistance in parallax removal and serves as a check for point marking accuracy.

Point Marking—A unique system molds marks into the film emulsion. Several marking dies are provided which range from a 200 micron circle to a 40 micron dot. A flagging mark is also included. Mark intensities may be varied by the operator to provide the optimum marks for particular emulsions, however, the marking system is fully automatic, once the operator has selected the proper reticle size and located it for a given point of interest.

Film Holddown—Diapositive plates and film chips from 70 mm. to 19″×20″ in size are held flat by means of a vacuum system. Vacuum pressure is variable for purposes of alignment and positive holding during operation.

Photo Display—Positive prints of the films on the photo stages are displayed on a photodisplay panel. A tracking light spot is projected onto the prints to indicate the actual location of the optical system axis as the films are scanned. This permits the operator to readily position any desired area of the film in the field of view of the optical system.

7. *Zoom 95 Stereoscope.* One of B & L developments which was originally intended primarily as an interpretation tool has found wide application as the viewing system used with hand point markers. The following characteristics have been found to be especially useful in point marking operations:

Zoom Magnification	—4 to 1 ratio
Working Distance	—5¾ inches
Optical Image Rotation	—360 degrees each side
Object Separation	—3 to 7¾ inches accommodated.

Bell Aerosystems Company

Bell Aerosystems Co. has developed an integrated mapping system for mapping areas Where ground control is not available, by the employment of an inertial navigator. Terrain clearance laser measurements are obtained to develop control in photogrammetric parameters, which are compared with inertial measurements to provide a bound for systematic photogrammetric error effects. It is shown that all ground control can be eliminated except for a single photopoint coordinate triad to serve as the datum for the mapping block.

U. S. Army Engineer, GIMRADA

GIMRADA's—activities in plotting theory and instruments in process as follows:

a. *Universal Automatic Map Compilation Equipment* (*UNAMACE*). A Universal automatic mapping system fabricated by the Bunker-Ramo Corporation, Canoga Park, California, is undergoing tests.

b. *Automatic Photomapper.* A contract has been awarded the Bunker-Ramo Corporation for fabrication of a rugged version of the Universal Mapping System

which will be suitable for mapping operations in direct support of the Field Army.

c. *Reconnaissance Plotter.* An analytical plotter which will accept various types of non-mapping, reconnaissance-type photography is under development at the Bendix Corporation, Southfield, Michigan. This activity is co-sponsored by Air Force and GIMRADA. Delivery is expected in early 1966. This plotter will utilize an analog-type computer.

d. *Ultrawide Angle Plotter.* An anaglyphic projection plotter designed and built under contract by Belfort Instrument Company, Baltimore, Maryland, is undergoing tests.

e. *High Altitude Plotter.* A projection-type plotter for 12-inch focal length photography fabricated by Aero Service Corporation, Philadelphia, Pennsylvania, under contract, will accept 9×9, 9×15, or 9×18-inch frame photography.

f. *AP/2.* Tests are in progress to determine the capabilities of the AP/2 Analytical Stereoplotter. A series of tests will be conducted to determine the plotter's suitability for military mapping from a wide range of types and sizes of photography. Mapping procedures using this instrument are also being developed.

Carl Zeiss/Zeiss Aerotopograph

As the results of extensive research done by the company several new products have been marketed. These are: the TS4 pocket stereoscope, the L 2 viewing desk and the N 2 mirror stereoscope. In addition the company is occupied with optical, mechanical and electrical problems. Thus they have completed the drop-line device for the Orthoprojector, produced the rotary lamelle shutter with a 1/3,000 sec. exposure time for aerial cameras and tested a color attachment for SEG V Rectifier. In addition the PSK stereo comparator and the automatic coordinatograph have been modified to a certain extent.

Electronic Associates, Inc.

In every-day photogrammetric research and routine production more and more requirement is placed upon a graphical representation of digital information and data. The EAI developed a dataplotter system which is capable of fulfilling this requirement. This system consists of:

3110 Dataplotter. Output—point plot only. Input—cards or punched tape. Will also generate directly on-line. Plots up to 100 points per minute.

3120 Dataplotter. Output—point or line plot. Input—cards or punched tape. Will operate directly on-line. Plots up to 100 points or 150 lines per minute.

3130 Dataplotter. 3110 or 3120 on-line with a computer or a data processing unit.

3440 Dataplotter. Output—line, point or symbol plots. Input—magnetic tape, punched tape, cards and manual keyboard. Points can be plotted at a rate of 350 points-per-minute. Lines may be drawn at a speed of 4,500 points-per-minute. Allows for use of 16 or 48-character symbol printer. As many as 180 distinct symbols-per-minute may be printed.

Galileo Corporation of America

Galileo Corp. has introduced Stereocartograph Model V as a more sophisticated version of the popular Model IV. The instrument is based upon the mechanical projection principle arranged in "horizontal" position which reduces the distance between the two cameras. The focal length range is from 85 mm. to 215 mm., so the instrument is suited for evaluation of super-wide-angle photographs. There are four correcting devices for each camera. Two are for correction of "systematic" instrumental errors and the other two for correlation of "accidental" errors of photographic images. The possibility of base-in and base-out enables the instrument to be used for aerial triangulation. The Stereocartograph Model V effectively can be used as a stereo comparator. As a further achievement the introduction of Stereosimplex II/c should be mentioned, which is the modification of Stereosimplex II/b designed for adoption of super-wide-angle photographs. The instrument is based on the mechanical projection principle. The instrument also is capable of solving small graphic or numerical aerial triangulation and for evaluation of oblique and terrestrial photographs.

General Aniline & Film Corporation

Extensive research has been conducted by the corporation in the field of Microdensitometry. As a result of this several microdensitometers have been made available to the photogrammetrist who is interested in the evaluation of samples of photographic materials where the recorded image is of importance. The G.A.F. precision photogrammetric instruments include microdensitometers, microline evaluator and micro-image scanners.

GOODYEAR AEROSPACE CORPORATION

Arizona Division has conducted a research program in All Weather Mapping sponsored by the U. S. Army Corps of Engineers GIMRADA. The objectives of this program are:

In addition to supplying radar mapping systems directed toward satisfying tactical mapping needs, the Army is also required to provide a capability for producing topographic maps under peacetime conditions in geographical areas which are continually obscured by clouds. To fulfill this need, the U. S. Army Engineer GIMRADA conducted investigations which led to the following proposed system concept.

The data acquisition portion of the All Weather Mapping (AWM) System would be contained in an RC-135 type aircraft. The major components for this airborne subsystem would consist of a terrain profile recorder (TPR), a position system (SHIRAN), and a high-resolution coherent Side-Looking Radar (SLR). Mapping information of an area would be obtained by flying the aircraft along various flight paths with all three sensors in operation. From these flights there would be recorded the area imagery in slant range from the radar, the aircraft's positions from the SHIRAN ranges, and the terrain profiles beneath the aircraft flight paths from the TPR.

It is the purpose of the current investigation to analyze the system parameters to determine optimum data acquisition techniques and flight configurations, and to establish design requirements for ground-based data processing equipment. This effort can be separated into two main areas of investigation:

1. Computer Studies—provide and demonstrate the validity of a computer program for the interpolation of contours from an array of spot elevations and determine the most suitable spot array configuration. Also, recommend a commercially available plotter along with all necessary modifications to provide a plotting unit capable of processing this data so as to provide a contour sheet for a 1/250,000 scale topographic map.
2. Orthographic Rectifier—establish and design requirements for an orthographic rectifier which will utilize the elvation data from the computer program to convert the slant range radar image to ground range and compensate for relative displacements caused by variations in elevation so as to provide a true orthographic radar presentation.

Akron Division has done several studies in support of mapping and reconnaissance data reduction. The most important from a point of view of the plotting theory and instrumentations are:

The Stereo Viewer. This is an optical device that is a product of a company-funded development effort. It projects a three-dimensional image from the overlapping portions of 70 mm. serial-frame photography. The operator sees a three-dimensional image by looking at a semi-specular screen without wearing any polarized or colored lenses. A unique optical system, employing a Fresnel lens, produces a spatial mode. that allows the photointerpreter to maintain an extended eye relief. Controls include scale-factor compensation, brightness, and displacement of one projected image with respect to the other in translation and rotation.

Psychophysical Viewer. The psychophysical viewer was conceived, designed, built, and installed aboard the JKC 63596 aircraft within three months under contract AF33-(657)-9476. It was used by the 665A project office for in-flight psychophysical tests. The viewer contains three independent optical channels that project imagery from 5-inch strip films onto three 11×11-inch rear-projection screens with coordinated, servo-controlled cross hairs. The three strip films can be driven at variable speeds in synchronism, or individually, in either direction. The cross hairs are driven in unison by velocity servos in response to a manually-manipulated tracking control. Intensity can be controlled and polarity of the cross hairs can be reversed (black vs. white). Live film can be displayed directly from an in-flight correlator and processor.

High-resolution Electronic Display System. Goodyear Aerospace is currently designing and fabricating an 1100 line electronic display system that utilizes a high resolution P-16 flying-spot scanner with a half mil spot size. The Monitor utilizes a 14-inch CRT with P-4 phosphor and a spot size of 3-mils.

High-resolution Radar Viewer. Under Contract AF33(657)-9461 for a high resolution radar data-processing and display investigation for the RS-70, Goodyear Aerospace

has studied and fabricated a breadboard of a rear-projection display system including two screens with coordinated cross hairs. Both displays are projected from a single image. In the small-scale factor display, the cross hairs move over the scene, while in the large scale display the scene moves under the cross hairs.

Change Detection Studies and Development. Under Contract DA-44-009-ENG-4462, Modification No. 2. for the U. S. Army Engineering Center, Fort Belvoir, Virginia, engineering studies were conducted on principles and methods to automatically detect changes in two photographs. Two techniques of change detection were evaluated.

Goodyear Aerospace is currently under government contract to design and fabricate a change detector that will quickly and accurately detect and display comparative differences that exist in any two photographs covering the same scene. This electro-optical instrument automatically registers the two photographs being compared, and within seconds presents changes as prominent bright areas on a background display of the two superimposed photographs.

Theoretical and experimental investigations are being conducted on long-term change detection under a classified contract AF33(657)11379, with ASD.

Synthesis of Radar Imagery. Basic research, development of techniques, and the fabrication of hardware for synthesis of radar images has been conducted to expand the operational capability of the ATRAN guidance system in the TM-76A Mace Missile. This included extensive studies of terrain classification, radar target characteristics, and simulation equipment. The coordinated efforts of cartographic, photographic, electronic, and optical scientists culminated in the activation and operation of the Air Force's Map Synthesis Section at Orlando Air Force Base, Florida. This facility is an integrated system for the generation, on a production basis, or synthetic radar reference films for the TM-76A Mace Missile System.

Mapping Study. Goodyear Aerospace conducted a program to extract mapping details from high-resolution radar photographs under Contract DA-44-009-ENG-4462 with GIMRADA. This work included the study of soil, minerals, geography, techniques of map making and transfer of map information. The objective was to identify the factors in radar photogrammetry that are pertinent in the mapping of information from radar returns. Results included development of procedures and techniques adaptable to an all-weather mapping system that uses high-resolution radar as a terrain sensor.

HRB-Singer Corporation

For over a decade HRB-Singer has conducted research and development programs applicable to airborne infrared thermal mapping systems and other electronic information projects. Based on these experiences the Company made available for military and commercial use, several remote sensing systems. Among others the Airborne Radiometer, Model AR1, the Reconofax VI infrared thermal-mapping system. Furthermore several studies conducted by the Company in connection with the application of these systems in the field of oceanography, infrared imagery for mapping drainage patterns and for fire detection.

Kelsh Instrument Company, Inc.

The Kelsh Instrument Co. has recently developed a dodging projection type printer for making diapositives. The printing time 40 to 90 seconds depending upon plate speed and negative density. Scale can be varied to produce uniform scale diapositives taken with cameras of 150 to 156 mm. f.1. The printer also can be used to print negatives taken with cameras of other focal lengths, to produce a 1 to 1 diapositive. The company has also completed development of a full-size inverse telephoto type projection lens which can be used in the latest model K-100 plotters.

Kern Instruments, Inc.

The Kern PG 2 Stereo Plotting instrument is well-known to the photogrammetrist of this country. The several unique features embodied in this new plotter have been reported to the photogrammetric society; the latest of these was given by F. Goudswaard, on the "Compensation for Earth Curvature Influence in the Kern PG 2" reported to Tenth International Congress of Photogrammetry, 1964. However, the Company is presently engaged in a research for the further development of PG 2. Unfortunately, details on this program are not available at the time of this report (December, 1965).

MARK HURD AERIAL SURVEYS, INC.

The technicians of Mark Hurd's Santa Barbara Office are perfecting a "Miniprinter" which will enable a photogrammetrist to print aerial negatives at a 50 per cent reduction. This is planned to save time and space in the indexing phase of photogrammetric practice and the filing of proof prints.

SYRACUSE UNIVERSITY

Syracuse University has completed a study of Photogrammetric Measurements of Dynamic Displacements. The study was sponsored by National Science Foundation and conducted by B. A. Wasil, D. C. Merchant and J. J. Del Vecchio. An analog method has been developed during the investigation in order to reconstruct the bundle of imaging rays from two or more camera stations. The reconstruction is made to generate a three dimensional optical model of the vibrating plate effectively fixed in some selected phase of the oscillatory cycle. The Porro-Koppe principle has been employed. Viewing of the model is accomplished through stereo observation of the processed negatives directly by means of special stereoscope located above the projection camera. The three dimensional model is plotted by introduction of a reference mark into optical model consisting of a point source of light and located under the projection cameras. The instrument is able to provide the evaluation of close-up photographs.

THE BUNKER-RAMO CORPORATION

The Corporation has been engaged in the past with research on automatic map compilation from stereo aerial photograph. Automatic extraction of altitude data and simultaneous preparation of an orthographic projection photograph as a step in the production of topographic maps was proved feasible with the development of the Automatic Map Compilation System. A second generation system for use in a production environment, the Universal Automatic Map Compilation System equipments (UNAMACE) have passed initial acceptance tests. These systems use hybrid analog and digital techniques to locate corresponding imagery on stereo pairs of aerial photographs to determine attitudes and expose a new photograph on which the image elements appear in correct map relationship with all photographic distortion removed. These instruments besides being fast and accurate compilation instruments, have a 4-micron r.m.s. capability as comparators, and the associated computer has been programmed to perform resection calculations.

WILD HEERBRUGG INSTRUMENTS, INC.

An experiment with super-wide-angle photographs using Wild A9 Plotter has been completed as reported by Prof. Hugo Kasper, Federal Institute of Technology, Zurich. The experiment utilized photographs taken of 2,900, 4,400 and 7,200 feet altitudes over a test area that had previously been surveyed for cadastral purposes. The standard error for the A9 compilation with the lowest altitude found to be ± 23 cm. horizontally and ± 18 cm. vertically. With this investigation it has been pointed out that the users of the A9 and B9 group of instruments in developing countries are able to produce engineering plans or cadastral maps at the scale of 1:2,000.

Recent Research and Development Activities in Aerotriangulation

by H. F. Soehngen

A NUMBER of large photogrammetric organizations have continued research and development programs in aerotriangulation. The major emphasis is on the development of analytical aerotriangulation techniques utilizing medium and large size electronic computers.

A report in detail of the activities of the agencies which answered a questionnaire will indicate the scope of the large effort being exerted to automate this branch of photogrammetry.

U. S. GEOLOGICAL SURVEY

The current investigation of the Topographic Division encompasses two general approaches to the aerotriangulation problem, the analytical and semianalytical. Both systems utilize electronic data processing procedures in conjunction with digital readout equipment.

The *analytical* system derives both vertical and horizontal positions of ground points by a purely mathematical approach of an iterative, simultaneous, least squares adjustment based