RESEARCH COMMITTEE

Gomer T. McNeil, Chairman, U. S. Naval Photographic Interpretation Center

THE 1950 Research Committee has already requested fifty photogrammetric or related organizations to submit a brief outline of such photogrammetric research conducted during the past year as may be of general interest to the readers of PHOTOGRAMMETRIC ENGINEERING. The Committee expresses its appreciation for the excellent cooperation received. Further requests are being made of other organizations. The following contributions have already been received; others will be published in later issues of this Journal.

The Visual Subcommittee, under the chairmanship of Mr. M. Salzman, U. S. Navy Hydrographic Office, in cooperation with various governmental agencies, is conducting tests on the *stereoscopic acuity of multiplex operators*. A subcommittee report will be presented for publication in the December issue of PHOTOGRAMMETRIC ENGINEERING.

ANSCO

Ansco has announced a new film for photo lithographers which enables them to make printing plates faster and more economically. Advantages of this new film, known as *Ansco Reprolith Ortho Type B*, include shorter exposure time, high orthochromatic sensitivity, maximum latitude in development, fine resolving power, clarity in white areas, fine dot etching qualities and steep gradation. Shorter exposure times enable lithographers to deliver rush work faster and to cut costs through time-saving. Higher sensitivity and use of filters permit better copies which would otherwise require hand work on the negatives. In tests, Reprolith Ortho Type B's ability to register fine detail proved higher than with average film, stains and discolorations were eliminated, and dot edges came up pin-point sharp in shadows.

Ansco Reprolith Ortho Vinyl Base Film, the new graphic arts film of extreme dimensional stability, is designed for map-making, line separations and photo template work. This film has an emulsion of high contrast and speed characterized by high orthochromatic sensitivity. Its use with filters permits improved rendition of copies which otherwise would require hand work on the negatives.

ARMY MAP SERVICE

Since December 1949, no new research work in photogrammetry has been initiated at Army Map Service. Research has continued however on *utilization of the stereoplanigraph for aerial triangulation*. Final results of this work have not yet been prepared. Further development work on techniques for *compiling medium scale maps (1:250,000) from high altitude vertical photography* has continued. The first production of this type has just been started and development of techniques on this work is continuing. (A descriptive article by Mr. Brandt is included elsewhere in this issue.—*Ed.*)

BUREAU OF PUBLIC ROADS

OUTLINE FOR RESEARCH, RESULTS OF WHICH SHOULD IMPROVE AND INCREASE THE USE OF PHOTOGRAMMETRY IN HIGHWAY ENGINEERING

Printing of aerial photograph images on sensitized transparencies in order that proposed highway locations and solutions to site problems might be illustrated by a draftsman over the image on the same transparency. The photographic

image and the drafting would be reproduced later as an engineering plan for the actual construction of a highway, bridge or other structure.

Stabilization of photographic paper without the use of wax, as the wax placed around photographic paper to prevent it from absorbing moisture in the developing, fixing and washing processes, causes the emulsion-containing photographic images to be easily scuffed off by continued use of the photograph. The photographic emulsion must be well adhered to the photographic paper so that it will not scuff off during continued use, yet the paper must be so stabilized that it will not change in size, causing distortion of image and errors in parallax measurement.

The interpretation of aerial photographs for engineering purposes such as determination of traffic in quantity, direction of movement and places of congestion in metropolitan areas; causes of pavement failure, cut slope and embankment slope failure; causes of erosion by water and by wind; determination of soil types and condition for engineering purposes; interpretation of the types of flora in the classified climatic zones of the earth; interpretation of the drainage patterns to determine how they may be worked with and controlled; perspective use of vertical and oblique photographs to illustrate proposed solutions to highway engineering problems.

Determination of the proper scale of photographs for the following purposes: (1) reconnaissance of an area by stereoscopic examination of aerial photographs to determine all feasible routes for a highway; (2) reconnaissance of feasible alternate routes of a highway to determine the best one by preliminary survey through a stereoscopic examination of the aerial photographs, supplemented by field investigation where necessary; (3) use of the photographs taken for reconnaissance of feasible alternate routes to prepare topographic maps by precise photogrammetric methods for the preliminary location of a highway on the best route.

U. S. COAST AND GEODETIC SURVEY

Research in the Division of Photogrammetry of the U. S. Coast and Geodetic Survey in 1950 is a natural consequence of the demand for more and better maps in less time, together with the recent advancements in instruments and techniques made in this and other mapping organizations. The items discussed here were not necessarily planned nor anticipated at this time, but they are the subjects of study because of their relative importance to the present mapping program. Other deserving problems also exist which cannot be studied now because of manpower limitations, whereas some problems are normally being studied by individuals on their own initiative and hence are not reported herein.

Radial line plotting with hand templets is still being used successfully with both nine-lens photographs and enlarged single-lens photographs. During the past year, the difficulties with the distortions of materials have been largely overcome by the use of "master" templets, a larger number of reference marks in the aerial cameras, and vinylite templets. Troublesome mistakes are partly overcome by improvements in the organization, routine, computation forms, checking system, special plotting tools and scales for control points, base grids ruled by machine on vinylite and training personnel in "unmistakable" identification of control points on the photographs in the field. Field and office workers are frequently interchanged for a few months for their mutual information and a better understanding of the other's problems. The proper training of personnel remains as one of the more important obstacles to be overcome.

Partly because of the recent widespread interest in the *quality of aerial photography*, the theoretical and practical elements involved in making a "perfect" photograph are being studied in detail to show the correlation of the various factors; namely, exposure meter reading, contrast brightness range in the subject, exposure (time and aperture), developing agent, time of development, and the desired contrast and density of the photographic print or diapositive. The data have been the general knowledge of the expert photographer, but the information has not been applied very well to aerial photography, possibly because of false meter readings caused by atmospheric haze. A densitometer and an extinction meter have been procured to facilitate the research, and the timing and efficiency of the aerial camera shutters have been studied.

The added work load, which is created partly by the outside popularity of the nine-lens photograph, has necessitated the *construction of a second transforming printer*. All parts will have been received this year, after which assembly and adjustment will begin.

The Kelsh plotter is being studied to determine its relative accuracy and favorable methods of application to the work of this Bureau. A pantograph is being attached to reduce the scale of compilation, and the frame of the plotter is being extended to include the pantograph. Radial line plots of hand templets made with Kelsh plotter are being tested to ascertain the relative accuracy and practicability of using this method to bridge horizontal control. A test for flatness of the model showed no discrepancy in elevation larger than 0.2 mm., which is almost within the limit of one's ability to read elevations, and demonstrates the accuracy of design and manufacture of the distortion cams.

This summer's work in Alaska in establishing vertical and horizontal control for photogrammetric compilation should furnish useful information for future control programs. A combination of theodolites, phototheodolites, pontoon airplanes, weasels, trigonometric and barometric leveling will be employed whereever they are considered to be the most practical. The results of the field work are to be used with vertical and horizontal bridging awith multiplex and stereoplanigraph.

The elevation indicators of the Reading plotters have been redesigned for easier reading using the optical projection principle, and machine work on them has begun. A less costly method is sought to transform large-scale transparent multiplex sheets into satisfactory composite smaller-scale transparent map manuscripts without redrafting. This operation might seem to be a simple application of photographic reduction, but actually the problem is complicated by several troublesome factors.

Thus, a brief description is given of some of the problems that are receiving consideration in the Coast and Geodetic Survey. To obtain the answers to these problems will require time, and then the answers may not be what is desired or anticipated.

DEPARTMENT OF THE NAVY

Unclassified photographic and photogrammetric research projects presently under consideration by the Bureau of Aeronautics:

U. S. NAVAL PHOTOGRAPHIC CENTER

1. To develop a 16 mm. *motion picture camera for recording television screens.*
2. To develop a *special optical printer for use with brittle or shrunken motion picture film.*

U. S. NAVAL PHOTOGRAPHIC INTERPRETATION CENTER

3. To develop *ground methods of camera calibration* for a variety of anticipated environments:
   a. To establish standards of precision in camera calibration data in accordance with different photographic metrical requirements.
   b. To prepare a guide for use by photographic personnel assigned to metrical photographic operations.
   c. In order that the precision obtainable from various calibration methods may be clearly defined, certain basic investigations are being conducted with respect to:
      (1) The existence and magnitude of emulsion creep.
      (2) The characteristics and magnitude of plate and film deformation due to spring and vacuum pressure against fiducials.
      (3) The characteristics and magnitude of plate and film deformation due to emulsion pull after exposure.
4. To develop a *method of air camera calibration:*
   a. The object of this project is to determine the existence or absence of systematic errors from air exposures, and to verify ground camera calibration data.
   b. An explicit solution to the space problem yielding the elements of exterior and interior orientation, requiring the ground and camera coordinates of seven points, has been developed.
5. To develop *a portable stereoscope:*
   a. Sturdy construction, light in weight, and compact in size.
   b. Adjustments for: scale change, focal length change for different powers of magnification, and moving stereoscope in x and y directions.
6. To develop a *method of exterior angular orientation based on geometric properties* rather than imaged ground control.
7. To develop a *comprehensive parallax reference system* providing a greater utility of the differential parallax method.
8. To develop *two analytical methods of photogrammetric control extension:*
   a. Rapid
   b. Precise.
9. To *evaluate Zenith camera position determination* with emphasis on the photographic and instrumental errors that prevent this method from being comparable to current precise methods in accuracy.
10. *Installation and testing of special glass grids for cartographic cameras.*

EASTMAN KODAK COMPANY

Of interest to the photogrammetrist is the addition of *Kodagraph Auto-Positive Film and Cloth* to the previously existing paper line.

Kodagraph Auto-Positive Film, available in 30 and 100 ft. rolls in standard widths up to 48 in., prints directly to a positive without a negative step. Exposure is accomplished on standard high intensity printing equipment including blue-print or direct-positive machines, and vacuum frames. It can be handled in normal room or shop illumination, and processed in standard photographic solutions.

Because of its exceptional ability to reproduce fine detail crisply and sharply, it is particularly suited to map reproduction work. The base material has high dimensional stability, and as both sides have a matte surface, additions and corrections can be made in pencil or ink on either side. Original lines can be removed with eradicator solutions or a knife.

ENGINEER RESEARCH AND DEVELOPMENT LABORATORIES

The following is a list of unclassified research and development projects and investigations now active at the Engineer Research and Development Laboratories, Fort Belvoir, Va.

1. Development of a *motorized photomapping equipment train* designed for operation of Army Photomapping Units in the Field. This train consists of a series of van-type trucks with expansible sides which will contain equipment and facilities for computing, plotting, drafting, editing, copying, supply, and mosaic compilation.

2. Development of an *automatic focus reflecting projector* for use in projecting opaque objects, such as photographs or maps, onto a map manuscript so that details contained therein can be rapidly traced for map compilation. This instrument will project a 9″×9″ area at any magnification from $\frac{1}{3}$ to 3.5 with controls so designed that the projection is in sharp focus at all times.

3. Development of an *automatic focus rectifying printer* for quantity production of rectified or ratioed prints for controlled mosaic compilation. The instrument will rectify 9″×9″ photography, both 6 and 12 inch focal lengths with tilts up to 20°, at magnifications ranging from 0.6 to 3.5 while maintaining sharp focus.

4. Development of a *rectifying printer* designed to rectify 6 inch photography with tilts up to 70° (obliques of tri-metrogon photography) as well as near vertical photography. The instrument will be provided with accurate scales and circles on all motions so that they may be precisely set to computed values.

5. Development of *oblique multiplex projectors* for use in exploiting oblique tri-metrogon photography to the fullest extent in topographic map compilation.

6. Development of such *tri-metrogon plotting equipment* as the photoangulator, mechanical slotted templet set, and oblique sketchmaster to improve wartime equipment and to provide one type of equipment suitable for use throughout the Department of Defense.

7. Development of an *oblique height finder* suitable for use in measuring elevations from overlapping pairs of high oblique aerial photographs.

8. Development of a *portable stereoscopic plotting instrument* suitable for use in the field for the compilation of topographic maps. This will be a Ryker plotter modified to meet Army requirements.

9. Development of an *improved mirror stereoscope* to overcome limitations of existing standard equipment.

10. Development of *dimensionally stable cartographic bases*, both opaque and translucent, for use in map compilation processes.

11. Investigation and *test of foreign-made photogrammetric instruments* to determine their characteristics and relative merits. Instruments being studied include the Zeiss Stereoplanigraph, Wild Autograph Model A-5, Wild Autograph Model A-6, Poivilliers Stereotopograph type B, Poivilliers Stereotopograph type C, and the Cambridge Stereocomparator.

12. *Investigation and test of the Kelsh plotter* to determine its application to military mapping.

FAIRCHILD CAMERA AND INSTRUMENT CORPORATION

The developments which will be described have been performed on contracts under the direction of the following military authorities. Their vision and assistance have been essential in the successful completion of these developments.

Captain John H. McElroy, Director, Photographic Division, Bureau of Aeronautics, Department of the Navy, Washington 25, D. C.

Colonel George Goddard, Director of the Photographic Laboratory, Air Materiel Command, Wright-Patterson Air Force Base, Dayton, Ohio
Dr. R. S. Zug, Aberdeen Proving Ground, Aberdeen, Maryland
Special Devices Center, Office of Naval Research, Sands Point, Port Washington, New York
Commander L. W. Parrish, Commanding Officer, U. S. Naval Photographic Center, Naval Air Station, Anacostia 20, D. C.

FAIRCHILD CAMERA AND CALIBRATION LABORATORY

A Calibration and Test Laboratory for Precision Aerial Cameras is now being installed at the Fairchild Camera and Instrument Plant in Jamaica, N. Y. The equipment in this Laboratory has been selected or developed to provide means of determining the high-quality performance of the Fairchild Precision Aerial Cameras so that they may be certified as complying with the rigid specifications set for these cameras.

The specialized equipment designed and being built for the above purpose is the result of long planning and consultation with men prominent in the photogrammetric field. The ideas of Dr. Irvine Gardner, Dr. Francis E. Washer, Dr. L. E. Howlett, Dr. K. Pestrekov, Mr. Eldon Sewell, Mr. Paul Pryor and Mr. David W. Mann, combined with those of the experienced Fairchild staff with its 25 years of Camera Engineering background, are embodied in this equipment.

The major piece in the Laboratory will be the *Precision Camera Calibrator.* This huge instrument, which weighs well over a ton, is a modification of the original Precision Camera Calibrator developed by Dr. Francis E. Washer and F. A. Case at the National Bureau of Standards as reported in the December 1949 issue of PHOTOGRAMMETRIC ENGINEERING.

It was Fairchild's desire to have a single all-inclusive photographic test which would provide on one test plate all the necessary data to establish the calibration accuracy of Fairchild Aerial Cameras. This meant that the aperture of the calibrator must be such that limiting resolution tests could be made. To accomplish this it was necessary to use lens apertures of almost 2″ in diameter. The definition requirements for the collimator objectives being a maximum, increasing the aperture of the lenses over those used in the original model at the Bureau of Standards, required a corresponding increase in the focal length of the lenses. The size of the instrument, although held to a minimum, thus became many times that of the Bureau of Standards equipment.

The Calibrator is composed of 33 Collimators positioned at known angles. It is fabricated entirely of meehanite for rigidity and stability, and the efficiency and accuracy of its many details reflect the experience of Mr. David W. Mann, who is well known for his special equipment in the field of optical design and in whose Laboratory the Calibrator design was crystallized and is being fabricated.

The Fairchild high precision camera lenses, camera cones and completed cameras will all be tested on this Calibrator. The design is such that it will be possible to expose either film or plates on the Calibrator, the analysis of which will provide basic data for the certification of Precision Aerial Cameras on the following points.

1. Resolution (on specified emulsion plates on film).
2. Equivalent focal length of lens.
3. Calibrated focal length of lens.
4. Radial Distortion.

5. Tangential distortion.
6. Position of the principal point as referenced by the fiducial markers.
7. Determination of the 90° condition (perpendicular bisection of lines produced through opposite fiducial markers).

The lenses used in the Calibrator were recommended by Dr. K. Pestrecov of Bausch & Lomb. They are highly color corrected and their definition is excellent.

The dimensions of the resolution patterns on the collimator reticles have been corrected so that the resolutions of all off-axis targets can be read directly. This was accomplished by an ingenious photographic method, too complicated to be described in detail, but the accuracy is such that the distortion of the targets have been held to less than 2%, and the balance of the white lines to black in any one pattern to less than a 5% difference.

The entire unit is being vibration isolated on a large separate mounting to a natural frequency of 80 cycles/minute, damping being instantaneous.

Focusing Cone. In order that the photographic focal range of the 6 inch Metrogon Lenses, being used in the Precision Aerial Cameras, may be investigated, a *Precision Focusing Cone* for holding the lenses has been designed and fabricated at Fairchild. This cone positions and maintains the entrance pupil of the lens at the center of collimators of the Calibrator. The design is such that the focal plane moves parallel to the rear lens flange mount, maintaining parallelism within 0.0001″ full indicator reading, for all positions of the focal plane. The flange focal distance is immediately obtainable from the test, or conversely, the flange focal distance can be set and the selection verified by test.

Other standard pieces of equipment for accurate analysis of results in this Laboratory will be:

1. *The Mann Comparator* which measures distance up to 12 inches with micron increments.
2. A *Bausch and Lomb quality binocular microscope* mounted over a homogeneously illuminated stage.
3. *A Bausch & Lomb micrometer microscope* on precision ways, capable of setting fiducial markers to an accuracy of o.oool."
4. And a *film flatness test* of high sensitivity developed by the Fairchild Engineers.
5. *Accurate optical calibration equipment* for maintaining accuracies.

The Laboratory is air-conditioned, temperature and humidity being maintained approximately constant.

It is expected that additional precision test equipment will be added to this Laboratory, as the search for new designs and precision equipment proceeds.

Since the trend is toward more measurements at greater accuracy, the Fairchild program provides for additions of new equipment when available. Fairchild intends to continue to offer products keyed to changing requirements, and this measurements laboratory will be a vital factor in the success of our efforts.

ENGINEERING CAMERA TESTING EQUIPMENT

In order to insure that the quality of our developments are proven out in all respects, we have found it necessary to construct equipment which is quite specialized and not usually found even in organizations much larger than ours. A few of these special items are mentioned.

Recording Shutter Tester. The need for a simple, consistent and authentic method for shutter testing led to the development and construction of the present tester. Based fundamentally on the investigations conducted by Mr. Amron Katz, Physicist at Wright Field Photographic Laboratory, our tester represents a combination of equipment utilizing a photo cell pickup unit, an oscilloscope, a special calibrated oscillator, voltage multipliers, a microphone pickup and

mounting fixtures. These components are assembled as a self-contained unit so that any size shutter up to 5 inches in diameter and with speed ranges from 1/2,000 to 1 second can readily be installed and tested. The use of an automatic, single-frame, 35 mm. recording camera provides a permanent record.

Platen Flatness Tester. The exacting requirements for platen flatness in mapping cameras and the requirements of certification of this flatness by our customers led to a great deal of research and culminated in the construction of this tester. The use of a casting which has been machined, normalized and then scraped to within the required tolerance of 1/10,000 of an inch, a ceramic surface plate which is flat within 1/10,000 of an inch and a special type of indicator which reads to 1/10,000 of an inch provide means for supplying the most accurate data yet supplied to mapping agencies on platen flatness. This equipment is so assembled that the cameras are tested while in their normal operating position and under normal loading.

Explosion-Proofing Tester. The requirement for explosion-proofing airborne equipment led us into the development and construction of an explosion chamber. Components which are capable of setting off explosions are operated in this chamber under various conditions in an explosive atmosphere, the absolute pressure of which can be simulated to range from sea level to 40,000 feet.

AUTOMATIC EXPOSURE CONTROL

Considerable attention has been given to the problem of automatic control of shutter and aperture settings. The program takes into consideration aerial photography of various terrains as well as air-to-air and ground-to-air recording of targets against a sky background.

Within the past year a system has been devised which utilizes a barrier-layer type sensing device. This output is first compared to a computer voltage and the amplified difference voltage is then used as the input to a pair of control motors. The control circuit is so designed that the shutter exposure is preferentially controlled with the aperture supplementing only at relatively high brightness levels.

The associated computer handles parameters such as film ratings and filter factors so as to produce a reference in accord with the particular conditions.

Fairchild is engaged in a continuing investigation aimed at further improvement of computing, sensing and control equipments peculiar to this problem. Investigation of sensing devices is especially aimed at securing correspondence of spectral sensitivity in a system which will permit a variety of emulsion-filter combinations. In addition, the relation between average brightness reading of sensing devices and brightness distribution in actual fields is being considered.

The over-all coordination and improvement of this art represents a challenging and current problem keenly felt by this organization.

A NEW SERIES OF BETWEEN-THE-LENS SHUTTERS

We are constantly conducting investigations and performing developments for improvement of our present equipment and trying to anticipate the needs of the industry. In line with this policy we have developed a new type of shutter which is a great improvement of shutters of this type in the past.

The outstanding characteristics of the newly developed, dual-leaf center between-the-lens aerial camera shutter are its high speed, high efficiency, compactness, versatility and long life. A valuable feature of the design is that it has made a "drawer-type" of shutter possible which can be inserted between the elements of a lens without separating them.

This shutter employs two separate leaf centers driven by separate springs. The first set of leaves opens the aperture and trips the second set to close the aperture. The springs and leaf centers are wound by a one-revolution winding cam which operates two cam followers that are linked to gear sectors and winding pinions on the spring centers. The winding is performed sequentially to keep the shutter aperture capped while cocking the drive springs.

Each mainspring drives its associated leaf center through a mechanical linkage which provides a force multiplication at the beginning of the stroke and which accelerates the moving system very rapidly. This linkage also causes the leaves to be accelerated at the beginning of the stroke, and decelerated at the end of the stroke in a relatively gradual manner. Such controlled application of force in one direction, as opposed to the push-pull application of force in conventional aerial camera shutters, enables use of lighter shutter leaves and results in much longer life for the mechanism.

Because the driving member in each leaf center rotates through only 180°, use is made possible of a highly efficient snubber, which absorbs the kinetic energy in the moving system gradually and without the shock of striking a fixed stop. Also, the 180° rotation permits the driving member to be driven in one direction by the spring during the tripping of the shutter, and in the opposite direction against the spring force during winding. This eliminates the possibility of overwinding or double-tripping the shutter springs as might occur in the conventional aerial camera shutter.

Two methods of speed control have been developed. Both methods have been made possible by the use of two separately actuated leaf centers.

The mechanical system of speed control provides a variable delay between the fully open position of the opening leaf center and the tripping of the closing leaf center. Since the timing mechanism only has to control the tripping function and not actually retard the main shutter driving cam itself, as in the conventional aerial camera shutter, it is smaller and much less subject to wear. Also, a much greater range of shutter speeds can be obtained than with the retard on the conventional single main driving member.

The electrical system of speed control employs a tripping solenoid on each leaf center and a system for delivering pulses to these two solenoids and controlling the time interval between the pulses. This system provides a simple and accurate means of remote control of shutter speed without resort to a servo system. The use of an electrical timing circuit also permits the use of electrical inputs from a fully automatic exposure controlling system.

The new shutter design has been built in sizes ranging from a .250 inch aperture to a 2.500 inch aperture for aerial camera use. One size, built for use with the Metrogon lens, is only .070 inch in thickness. It has a speed range of from 1/10 to 1/400 second total open time, an efficiency at free speed of 65%, and has exhibited a minimum life expectancy in excess of 35,000 cycles through a temperature range from room temperature down to −65°F. Experimentally, speeds from 1/5 to 1/1,000 second total open time have been obtained.

K-40 CAMERA

The K-40 Camera is a Day Reconnaisasnce Camera having a 9×18 inch format and accomodating lenses of 12, 24, 36, 48 and 96 inch focal length. It can be used with either a 500′ or 1,000′ capacity magazine carrying film 18.470 inches in width. The magazines are of the image-motion compensating type having a moving platen with a built-in vacuum bellows. The continuous mode of magazine operation is used whereby the film velocity at the supply and take-

up spools is constant, and the velocity in the aperture is varied by the movement of two shuttle rollers which change the length of loops on either side of the aperture. The cycling rate necessary to produce 60% overlap and the image compensating speed bear a fixed relationship. An intervalometer is not needed. It is only necessary to vary the speed of the thyratron drive motor. This is accomplished by means of an electronic computer system, which is part of the camera control.

The camera control which can handle up to five cameras consists of either one or two primary controls. These controls provide for all the necessary flight adjustments. The altitude and ground speed are set into the primary control. This signal passes through the junction box to each of the individual secondary controls where it is further modified by setting in the lens focal length and angle of obliquity from vertical. The resultant signals then go to the thyratron amplifiers in the cameras thereby controlling the speed of each individual magazine drive motor. The primary controls also contain meters showing the amount of film remaining in each magazine, individual blinker lights and a single dial for simultaneous adjustment of shutter slit widths in all cameras.

One of the novel features of the camera is the focal plane shutter. The shutter slit is 18″ wide and travels across the aperture in the 9″ direction. Speeds of 1/25, 1/50, 1/100, 1/200, 1/400 and 1/800 of a second are provided. An efficiency of 81% at 1/800 of a second at f/6.0 with acceleration of less than 1% is realized. This is accomplished by the use of a 400 cycle continuous running synchronous motor, which drives two counter rotating electro-magnetic clutches. The shutter curtain travels in alternate directions. The counter rotating clutches are therefore alternately energized. The curtain travels 3″ before reaching the edge of the aperture which is sufficient to permit acceleration to synchronous speed before reaching the aperture. The drive assembly is decelerated upon reaching the opposite edge of the aperture by operation of an electrically released brake. Three inches of travel is allowed for braking thereby assuring a relatively gentle stop. The shutter bars forming the edges of the slit are attached to steel cables driven by pulleys. The curtain rollers are also driven at the same velocity thereby saving the curtain material from undue stress. The slit width can be varied at any time to change the relationship between the curtain drive pulleys by means of a small servo motor, thus affording remote control of shutter speed.

A time record appears on all negatives. This is accomplished by a selsyn transmitter in the junction box which sends a signal to receivers in all magazines causing a change in the number dial every second. The number prevailing at the time of exposure is recorded on the film. A magazine replaced after reloading will automatically "pick-up" the same number as the other magazines. This method of numbering the film will assist in sorting negatives after processing.

The weight of one camera equipped with a 1,000′ magazine and 24″ lens, including film weighing 67 lbs., is 296 lbs. The weight of the electrical control system is 57 lbs.

K-37 AIRCRAFT CAMERA

The K-37 Aircraft Camera, in conjunction with its shutter trip control, comprises a medium by which photographs can be taken at night from high altitudes, by means of photoflash bombs or synchroflash equipment, from aircraft equipped for this purpose.

A trip magnet holds the lens shutter in the ready-to-trip position. The shutter is tripped when the light from the photoflash bomb causes the shutter trip control to de-energize the trip magnet.

The K-37 Aircraft Camera accommodates the type A-5A, A-9 or A-14 roll film magazine, which produces a 9×9 inch negative.

The camera body contains the drive mechanism, motor, radio noise eliminator, and two illuminated spirit levels.

The case drive is automatic and is synchronized to operate immediately after the lens shutter is tripped. The case drive may also be wound manually by a manual winding lever, which is provided.

The lens cone and shutter is designed for use with a lens having a focal length of 12 inches. The lens cone and shutter is detachable from the camera body and is interchangeable.

The lens shutter is furnished with a filter heater, which is detachable and interchangeable.

A new type Shutter Trip Control, containing a multiplier phototube and amplifier circuits, is provided to receive the light flash of the photoflash bomb and simultaneously operate the camera.

Sensitivity is greatly increased over that of the previous standard night photo shutter control, to permit working from higher altitudes and from reflected light from the ground instead of direct light from the flash bomb. In addition, the unit is designed for use under more extreme environmental conditions than the previous equipment.

In operation, the light sensitive multiplier phototube in the shutter trip control receives the light flash from the photoflash bomb. The electrical impulse from the tube is amplified by several stages of amplification. The shutter is held in a ready-to-trip position by the trip magnet which is in the plate circuit of the amplifier tube. Normal plate current is sufficient to hold the trip magnet, and when the amplified electrical impulse from the phototube is applied to the grid of the final amplifier tube the current is cut off, de-energizing the trip magnet, allowing the shutter to trip and the camera mechanism to operate through one cycle. In this way, the minimum time lag is obtained in initiating an exposure upon explosion of the flash bomb.

BALLISTIC CAMERA

The Fairchild Ballistic Camera is a precision measuring instrument for tracking an airplane or any other object in the sky. This camera is used in sets or pairs in separate locations, and synchronized so as to obtain complete coordinate data. Analysis of the train of airplane images on each photographic plate, together with the knowledge of the camera locations, permits the track of the airplane through the sky to be accurately plotted.

This camera incorporates features that insure improved target definition, greater accuracy and ease of operation over all models built to date. The basis for this is as follows:

1. An internal slit aperture with a shutter above it, thereby exposing the plate only to a strip of sky which contains the target. The camera operator views the target through a tracking telescope which is synchronized with the slit aperture and, when following the target advance, a coordinated motion of the target and the aperture is insured.
2. The camera body, accurately positioned photographic plate, long focal length and invar-type lens barrel all lead to a high precision camera with accurate data as the resultant.
3. A 39° angle of coverage.
4. A 30-power sighting scope to insure accurate azimuth orientation.
5. Synchronized exposure between master and slave camera to within less than $\frac{1}{2}$ millisecond.

6. Ease of adjustments through telescope flexibility, alignment with slave camera, lens focussing, frame changing, shutter openings and camera mountings.

7. The camera body is a rigid aluminum casting which maintains the photographic plate and the lens in strict alignment and to very close tolerances.

8. Adjustable mount to permit setting the cameras to a variety of accurately positioned attitudes to allow the greatest flexibility in range selection.

It must be kept in mind that these precision accuracies and adjustments are obtained in spite of the large bulk and weight of the equipment. The camera weighs 300 lbs. and the mount 2,000 lbs.

TYPE N-9 GUN CAMERA

This is a general purpose gun camera intended for use on fighter aircraft, gun turrets and gyro sights, to record the results of gun fire in combat and training on 16 mm. movie film. This is the first real replacement of the famous Fairchild GSAP camera so widely used in the last war.

The camera consists of a camera body, removable magazine, a set of four (4) interchangeable lenses, boresight and a remote shutter control box.

The camera body contains a 27.5 V.D.C. motor, gear train, speed change mechanism (for photographing at 16 or 24 frames per second), magazine drive sprocket, film advance claw, adjustable overrun control (settings from 0 to 3 seconds in one (1) second steps), magazine locking mechanism and a variable shutter which can be set for shutter speeds from 1/65 of a second to 1/1,000 of a second. The shutter speed can be changed on the camera body when accessible, or may be set from the remote control box on wing installations.

The magazine is a rigid aluminum casting with a hinged cover containing a gear train for driving both the feed and take-up spool sprockets, the necessary film guides, pressure plate, thermostat and heaters.

The interchangeable lenses supplied with the camera are 17, 25, 35 and 50 mm. focal length units.

The remote control box contains the "on-off" switch, fuse and knob controlled unit for changing the shutter speed in the camera body electrically.

DISTURBED OPTICAL AXIS CAMERA

The Distributed Optical Axis Camera is the end-product of a project initiated by the Special Devices Center, Office of Naval Research. It constitutes equipment intended to improve and simplify evaluation of photographic records in aerial gunnery training.

Incorporation of signals from an existing Fire Control Computer makes possible automatic deflection of the camera so that its optical axis coincides with the line of sight of the Fire Control Sight Head. Essentially this results in maintaining the recorded image of the target centered on a 16 mm. frame in a relationship directly indicative of tracking ability.

Due to the tracking intelligence available to and utilized by the deflecting mount of the Disturbed Optical Axis Camera and the resulting frame centered image, relatively long focal length lenses can be employed. This affords an obvious advantage over the conventional wide-angle, short-focal length gun camera with fixed axis mounting. The increase in image size and the elimination of coordinate translation are intended to provide greater speed and accuracy in evaluation.

The camera is magazine loaded (20 ft. capacity). Interchangeable 100 mm. and 15 mm. lenses are provided. Conventional Stick Switch firing and adjustable

overrun are incorporated. The camera uses standard 24-volt D.C. circuitry while associated control requires 400 cycle supply.

The over-all equipment is designed to result in a 2 mil accuracy of correspondence between Sight Head line of sight and Disturbed Optical Axis Camera axis.

PROJECTION PRINTER

This equipment was developed to fill the need of an automatic high speed enlarging printer for use with enlarging papers, printons and Aero color-duplicating film.

It is designed for use with 35 mm. double frame, 70 mm. and 5″ film all perforated with 35 mm. positive perforations and designed to operate both as a continuous printer and a step-and-repeat printer. In continuous printing the negative and positive materials are transported simultaneously, and printing is accomplished through a variable slit controlled by a continuous reading photocell exposure control.

In step-and-repeat printing, both the negative and positive materials are stopped during exposure. Between exposure the materials are moved one frame. The positive material may be advanced while holding the same negative for repeat printing. In these types of operation the time of exposure is automatically judged by a photocell judging circuit. The negative materials are indexed from frame to frame by means of perforations.

This equipment consists of a conso e which contains the supply spool, paper transport mechanism and all the control circuits for the unit, and a projection head that contains the negative drive mechanism, variable slit and projection system.

35 MM. RECORDING CAMERA

Testing high speed aircraft requires speedy photographic data recording. Fairchild has designed a camera which is suitable for both aircraft and laboratory use. It is a simple and rugged motion picture camera whose speed can be varied from 4 to 16 frames per second. The 35 mm. perforated film is housed in interchangeable film magazines with capacities up to 400 feet.

The camera can be operated manually or electrically and to add greater usefullness the power can be either 27.5 volt D.C. or 115 V. 60 cycles.

An intervalometer permits pictures to be taken at intervals of 1 per second to 1 per hour, and a special switch permits extra pictures to be taken between frames when the exposure interval is long. As an aid to fulfilling all of the requirements for 35 mm. Data Recording Cameras, Fairchild is producing another camera which can accommodate either standard or Bell and Howell perforations on 35 mm. film, and can accommodate commercially-available film magazines of 400 foot capacity. A selector switch establishes frame speeds of single frame, 4 frames per second, 8 frames per second or 16 frames per second. This camera operates on nominal 28 volt D.C. electric power. The camera is equipped with a 25 mm. f/4.5 lens, and the aperture adjustment is equipped with a locking device. The lens mount provides a focusing range of 20 inches to 100 inches.

Both of these cameras are designed to withstand the shock and vibration conditions usually encountered in laboratory data conditions. It is with such recording cameras that much of the military mapping aircraft and military mapping equipment can be evaluated and made satisfactory for the rigorous conditions which they must stand.

FAIRCHILD POLAROID OSCILLOSCOPE CAMERA

The new Fairchild Polaroid Oscilloscope Camera is designed to deliver a photographically accurate record of the oscilloscope trace, within seconds after the trace has occurred. This camera has many laboratory uses but of particular interest to the photogrammetrist is the fact that radar traces can be made immediately available for future reference. This means that immediately available radar maps are provided for air navigation, surface pilotage and for other specialized radar interpretation purposes. The camera is so designed that it is easily adapted to 5 inch diameter oscilloscopes, and with special adapters can be adapted to other oscilloscopes. This camera has a special new lens which is designated the Wollensak Oscillo-Anastigmat. This lens is 3 inch focal length and has a full aperture of f/2.8. The shutter provides time and bulb settings and also speeds of 1/25, 1/50 and 1/100 second. These speeds provide the full practical range for oscilloscope recording. Another feature of this particular camera is the fact that the oscilloscope trace can be studied while the photograph is being made.

HYCON MFG. COMPANY

A solution to the problem of *focal plane shutter slit design* for large size negatives, as worked out by Hycon engineers, may be of interest to members of the American Society of Photogrammetry. Providing slits for negatives of widths 18 inches or larger entails considerable difficulty due to the problem of supporting the slit edges without encountering edge curvature caused by curtain tension. In addition, these large negatives entail considerable difficulty in providing filters near the focal plane, due to their extreme size and manufacturing difficulties. Both of these problems were solved by the use of a plastic filter material mounted in the slit which both provided the light filters and gave mechanical support to the edges of the slit. This design has been successfully applied to a large camera, and appears to have considerable flexibility in slit widths and types of filters. The design is carefully worked out so that the slit weight is as small as possible.

NATIONAL BUREAU OF STANDARDS

The *new precision camera calibrator* has been put into operation and a paper entitled "*Calibration of Precision Airplane Mapping Cameras*" by F. E. Washer and Frank A. Case is published in both the *Journal of Research of the National Bureau of Standards* and elsewhere in this issue of PHOTOGRAMMETRIC ENGINEERING. This paper describes the use of the new instrument in the calibration of precision cameras.

Preliminary studies of "tangential distortion" have been made. It has been definitely established that prism effect in lenses or filters can contribute materially to this aberration. It is expected that a report will ultimately be published on this work.

Some progress has been made in the *investigation of photographic definition* using the resolving power chart with variable spacing suggested by Dr. I. C. Gardner. While this chart is intended primarily for use in variable contrast problems, interesting results have been obtained using the high contrast master test chart. Pseudo resolving power phenomena can be readily produced in out-of-focus images and the manner in which they appear can be predicted as a function of *f*-number, resolving power and distance from true focus.

U. S. GEOLOGICAL SURVEY

PHOTOGRAMMETRIC RESEARCH PROJECTS:

1. *Redesign of Kelsh Plotter.* Design work completed; instrument now in production.
2. *Performance tests of Twinplex Stereoplotting Instrument,* including actual mapping of an adequately controlled area.
3. *Development of a new type of projector,* having an improved system of illumination and a diapositive of approximately one-half negative scale, this giving better visibility in the stereoscopic model. To be used with either vertical or Twinplex photography.
4. *Completion of development work and test of Bauersfeld Panagraph* and other foreign photogrammetric equipment.
5. *Development of an improved tracing table for double-projection instruments.* New features include a counter-type device for reading elevations directly in feet at various scales, increased range of vertical motion of platen, and elimination of shadows on platen.
6. *Experimental project using PK 9-lens camera* to determine its suitability for reconnaissance mapping.
7. *Analysis of Airborne Profile Recorder results* to determine best methods of using Radar Altimetry spot elevations for various types of maps.
8. *Investigation of the applicability of Shoran-controlled flight lines.*
9. Continued investigation of the *use of the precise phototheodolite* for extending horizontal and vertical control with terrestrial photographs.
10. Continued development, in cooperation with the Armed Forces, of an *aerial camera lens of high resolution, with distortion reduced to a negligible amount.*
11. Formulation of *specifications for a new type of diapositive printer* in which, among other features, distortion compensation is accomplished by the use of an aspheric correction plate in conjunction with a projection lens of high resolution and precision, resulting in superior qualities in the finished diapositive.
12. Experimental project *using curved Multiplex diapositive plates to reduce or eliminate distortion,* particularly for control extension work.
13. Development of *improved supporting frames for Multiplex.*
14. *Development of an optical bench* suitable for the needs of the Geological Survey photogrammetric laboratory.
15. Development of a *uniform method of vision-testing* and establishment of *visual standards* for prospective operators of photogrammetric equipment.
16. Investigation and design of a *diapositive contact printer* having a single adjustable light source of variable intensity.
17. Development of an *improved type of removable diapositive plate* holder for Multiplex and other plotting equipment.
18. Continued development of a *device to eliminate anaglyphic viewing* and enable color photographs to be used in double projection instruments.
19. Development of *mobile stereo-plotting instruments* and field trial of same with stereo-compilation work being done in the immediate vicinity of project terrain. Possible advantages for large scale specification mapping —better topographic expression, and expedition of those projects involving both stereo and ground survey contouring.

U. S. NAVAL ORDNANCE TEST STATION, INYOKERN, CALIFORNIA

This Station has a particular interest in the field of photogrammetry as it applies to the inverse problem of mapping the flight paths of rockets, guided missiles, and aircraft from the ground and the determining of underwater trajectories of certain missiles.

To obtain more accurate data in this field of work, several important projects have been established for the development of *improved models of ribbon-frame cameras, trajectory cameras, cine-theodolites, and long range tracking telescopes.*

In addition, considerable effort has been devoted to improvements in the fields of precision timing and control of instruments, the evaluation and calibration of optical systems and mechanical components, the control of dimensional changes in film stocks, studies of black and white versus color films for recording purposes, and improved processing and data assessment techniques.

It is regretted that much of this information is of a classified nature. Interested parties, desiring further details on work of this type performed at Naval Ordnance Test Station, Inyokern, California, may address their inquiries to the Chief of the Bureau of Ordnance, Navy Department, Washington 25, D. C.

REED RESEARCH, INC.

Special emphasis has been placed on research and development in the field of photogrammetry at the laboratories of Reed Research, Inc. after our successful endeavors with our Autofocusing Reflecting Projector, Dial Gauge Meter Bar, Micro-viewer, and Projection Ruling Machine.

With the techniques acquired by our staff in the field of *special-purpose, high speed electronic computers*, we have been investigating the development of such equipment for photogrammetric applications. It may be mentioned at this time that the Three-Point Resection Method of E. L. Merritt, described in "PHOTOGRAMMETRIC ENGINEERING" December, 1949, has been programmed for high speed digital techniques, Other tedious computational operations are being examined for similar simplification and time savings with the advent of these new techniques. Computations performed with conventional desk calculators requiring iterative operations of several man-hours duration are being accomplished in fractions of a second with computers capable of as much as two million (2,000,000) manipulations per second.

Reed Research, Inc. has undertaken the further promotion and development of the late Professor H. L. Cooke's inventions in the cartographic and photogrammetric fields. Among the items are:

1. A method of producing *maps of a greatly improved type* in which substantially all available photographic and topographical information relative to the terrain depicted is shown clearly on a flat surface in precise planimetric relation corresponding to that of nature.
2. A method of producing a *relief map from aerial photographs projected upon a moldable or plastic material* such as plaster of paris or wax, of which the map is to be made, and sculpturing the map with the pictures thus projected upon it.
3. A method of *producing layered or laminated blocks of a carvable medium* from which relief maps may be made.
4. A method of *shaping or carving relief models* in accordance with a stereoscopic image projected upon the body of material to be shaped.
5. A method to provide *an aerial photograph which is correct in planimetry that can be used directly as a map* within any limits required in actual use.
6. Projection apparatus and method for *preparing three dimensional models of terrain* from planimetric maps showing contour lines of the earth's surface.
7. Equipment to *project details of a plane figure upon an uneven surface* without dislocation of the details.

8. Equipment to *produce orthogonal photographic representations of objects or surfaces* comprising portions of different elevation, which representations are free from errors or displacements due to parallax.

The last item (8) is known as the *Orthocamera* and a paper describing it is being prepared for future publication in this journal. In the accompanying cuts a conventional photograph (Fig. 1) of an engine cylinder is compared with its *Orthograph* (taken by the Orthocamera) (Figure 2). Complete detail to true scale is readily discernible on the Orthograph. The same technique applied to

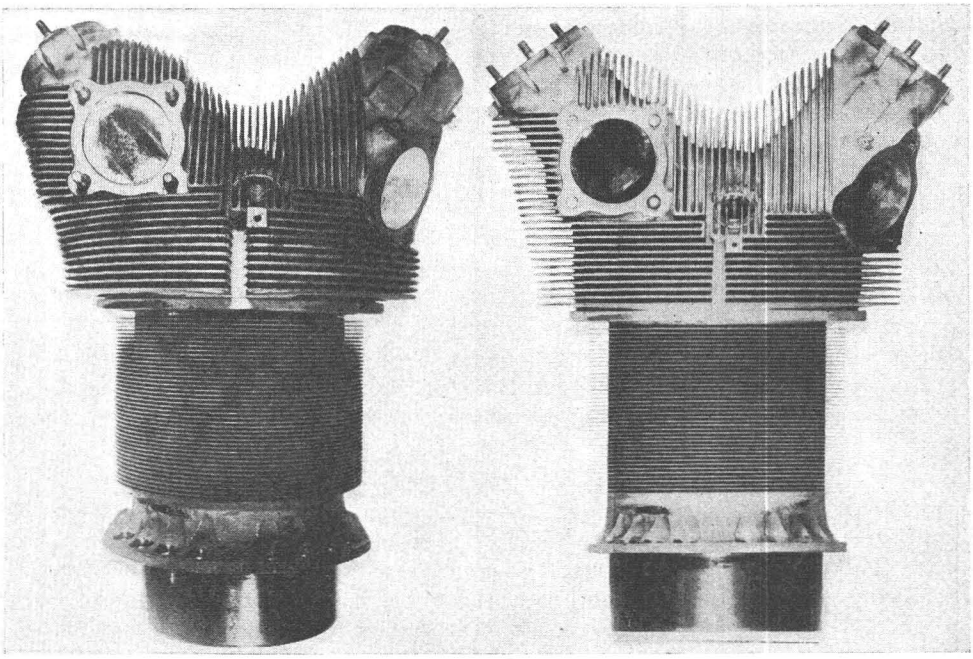

FIG. 1. Conventional photograph of an engine cylinder.

FIG. 2. Orthograph of the same engine cylinder made with the "Orthocamera."

cartography and photogrammetry will be described in the paper on the "Orthocamera."

SYRACUSE UNIVERSITY

1. A set of rigorous formulae were derived for *calculating image coordinates of ground points* specified by geodetic latitudes, geodetic longitudes, and elevations referred to an ellipsoidal sea-level datum, as these images would appear on high altitude photographs of given orientations (from, say, 40,000 ft. altitudes), with exposure stations specified by geodetic positions and with flight altitudes also referred to the ellipsoidal sea-level datum. The derivations of the necessary formulae are rather complex and have not yet been published, nor is it certain that they will be. The computations have been carried out to obtain data for a complete set of synthetic or "fictitious" photographs. These computations are naturally extremely heavy. They give, finally, a real set of coordinates for a set of fictitious photographs for test problems, representing considerably more than any heretofore available. This project has been completed. The results, if not already published, are available.

2. Considerable improvement has been made in our routine procedure for

analytical determinations of orientation. A new procedure has been worked out in detail *for photogrammetric control extension.* These computations have proved extremely satisfactory. However, a test computation on actual photographs, despite rigorous checks involved in the computations themselves, admittedly have not given control extension data of the accuracy anticipated. This investigation, in its present stage, appears to reveal distortion information which may prove to be very important. This project is complete at present, as regards the theory and the procedure; further tests are anticipated.

3. Two test projects of *investigating large-scale (low-altitude photography) plotting* by means of (a) the two-projector multiplex, and (b) the K.E.K. plotter have been carried out under the direction of A. O. Quinn by two of our graduate students. These projects were under way before Prof. Quinn's resignation in February, and have been completed under his direction, by more or less "remote control" since his departure.

UNIVERSITY OF ROORKEE, INDIA

Professor C. A. Hart has forwarded to the Research Committee his publication, "Some Aspects of the *Influence on Geodesy of Accurate Range Measurement by Radio Methods* with Special Reference to Radar Techniques." This paper is a reprint from "Bulletin geodesique," nouvelle serie, anne 1948, No. 10, p. 307–352. Professor Hart, formerly Professor of Surveying and Photogrammetry at University College in the University of London, now lists his address as: Vice Chancellor's Lodge, University of Roorkee, Roorkee, U.P., India.

WALLACE & TIERNAN PRODUCTS, INC.

The W.&T. Palmer Altirule. This instrument was developed in order to simplify the computation procedure for the Two-Base Method of Precise Altimetry. The Altirule is a computer which *solves a problem of similar triangles.* Knowing the elevations of the upper and lower base and the altitude readings at the bases and field station, it is a simple matter to set the computer for these values and read the elevation of the field station. The W.&T. Palmer Altirule is available to users of the Two-Base Method.

A new altimetry procedure—the Leapfrog Method—was investigated in cooperation with American Telephone and Telegraph Co. and Bell Telephone Laboratories. Results of an extensive test show the Leapfrog Method is comparable in accuracy to the Two-Base Method. Two observers, each with an altimeter, are required and the altimeters progress along the route with readings taken at successive field stations and comparisons of the two made at alternate stations. Since the two altimeters are relatively close together at all times, they operate under the same atmospheric conditions and wide pressure variations are not encountered. This contrasts with other methods where the roving instruments depart from the base station, and are apt to encounter different pressure conditions which are impossible to take into account. With the Leapfrog Method, the base station in effect is carried along the route by comparison at alternate field stations.

WILD, HEERBRUGG, SWITZERLAND

During the past few months, the firm has not completed any new instrumental developments. However, the following important investigations have been carried out:

1. A statistical *investigtaion on the attainable accuracy* of the Autograph A-5

and the Stereo-Plotter A-6. Test plottings on 50 A-5's and 70 A-6's have been carried out and analyzed.

2. Tests on the *performance of lenses* and methods to test such lenses were performed. The results are contained in the article, "Standardization of Tests Methods for Photogrammetric Objectives," by Professor H. Kasper (see page 633).

3. The mechanical parts of the WILD *aerial cameras* have been *revised and redesigned.*

4. *Series production of the RC-7 Automatic Plate Camera was started.*

5. *A new RC-6 Aerial Series Film Camera for reconnaissance purposes was submitted to tests.* This camera has a picture size of 13×13 cm. and a focal length of 165 mm.

DISCUSSION OF "APLICACIONES PRACTICAS DEL METODO AEROFOTOGRAMETRICO" BY ALFREDO WEIL

Bernard J. Colner, U. S. Coast and Geodetic Survey, Washington, D.C.

MR. WEIL, in his book "*Aplicaciones Practicas del Metodo Aerofotogrametrico*" assumes an error of ±20 meters for astronomic position determinations. This writer agrees with this statement. However, when these fixes are to be used for a network of control instead of first-order triangulation, the error as to their geodetic positions for mapping control will probably be much greater, because of the variations of the deflection of the vertical from place to place. The following paragraphs will demonstrate the possibilities of errors of great magnitude where astronomic position determinations have been used for mapping control.

The following is a translation by this writer from the "*Annuaria Pour L'An 1949*".[1]

"Maps established on an astronomic network—The existence of the deflection of the vertical and the matter of the reference ellipsoid and geoid, prove the impossibility of establishing an accurate large-scale map based solely on a network of astronomic positions. On maps thus established, distances between Voirol and la Bouzareah (7 Km. or 4.3 miles) and on the island of Hawaii (120 Km. or 74.6 miles), errors of 360 meters (1,181 feet) and 3,000 meters (9,842.5 feet), respectively, were found.

It can readily be discerned that only small-scale maps of little precision can be established with networks of control based on astronomic determinations. L'Institut Geographique National constructed maps of the Sahara region at a scale of 1:500,000."

The following are quoted from Mme. E. Chandon's and A. Gougenheim's article,[2] "Instruments for Observing Equal-Altitudes in Astronomy," and are inserted because of the importance of the astrolabe in establishing control.

"Gauss's equal-altitude method, which enables the latitude and longitude of a place to be determined simultaneously and by observations of the same nature, was hardly used during the XIX century. But during the past fifty odd years, astronomers and geodesists, anxious to render measurements of geographical positions easier and, incidentally, more accurate, have designed instruments more appropriate than the sextant for use with this method. . . .

"Accuracy of results—The results given by the prism astrolabe have quickly proved themselves to be most satisfactory, and account for the success which this instrument has met with among French and foreign geodesists since its appearance in 1903.

[1] "*Annuaire Pour L'An 1949*," Le Bureau des Longitudes, Gauthier-Villars, Paris, p. 157.

[2] Chandon, Mme. E. and Gougenheim, A., "Instruments for Observing Equal-Altitudes in Astronomy," "*Hydrographic Review*," International Hydrographic Bureau, Monaco, May 1935, pp. 45 and 54.