type is the assault model which has the culture features such as roads, names, etc., presented in a raised position. This latter is accomplished by etching in reverse the cultural features onto a zinc plate, spraying a thin coat of latex rubber onto the plate, and mounting the rubber skin thus derived onto the previously prepared base model. Advantages are greater legibility as well as ease in painting the cultural features onto terrain model.

Still other techniques are under investigation and include photography of models to provide shadow-relief plates for lithographic maps, procedures for quickly fabricating relief globes, the perfection of a flexible embossed relief map, and the use of sprayed metal and normal photo-engraving processes to enable printing on molded or developed surfaces.

Finally, I would like to point out two processes in the field of photo-lithography, which have been recently adapted to military map making. The first one is the process of making color separation negatives from colored, lithographic line maps by photographic means. Black images are separated by means of the effect of "solarization" whereas the blue and red images are separated by means of the "Herschel" effect. Separation of the colors of a map in this manner can be done in about one-fifth of the time and cost of ordinary methods, a factor which should be of distinct advantage in time of emergency. The second process is the making of direct color copies of colored lithographic line maps in the camera. Because of the simplicity of this direct method of reproduction and the relatively lower cost involved, this process should be useful in the preparation of library file copies of colored maps as well as in those cases where a few copies of a map are desired in color rather than in black and white.

I've portrayed here rather sketchily a few of the strides which have been made recently in the field of military mapping. In the most part these studies have been due to the individual and collective efforts of members of this Society. Your continued efforts are still very much desired. As the technical phases of warfare become even more complex, professional groups such as this one become a vital part in the solution of such technical problems. We all have a stake in the final result and all have a responsibility as members of this Society to contribute to the common public good—each must contribute to the utmost of his ability.

PRESIDENT SANDERS: Thank you, Colonel Mills and Major Nowicki, for your excellent presentation on military mapping.

The next speaker on the program causes me to think a little bit on the old-time vaudeville act of switching identities quickly. He has been very instrumental in the success of this meeting through his efforts in connection with the exhibits, but he has put away his hammer and overalls and will carry on with the technical phase of the meeting.

He is well qualified as an expert in his phase of photogrammetry. He was educated at the Massachusetts Institute of Technology, has been actively engaged in mapping for the Alaskan Branch of the Geological Survey, and is one of the men instrumental in the development of the trimetrogon system.

He has had a large part in the work which has been done on the photoalidade. In short, we could not pick a much better man to speak* on the subject of the photoalidade than Mr. David Landen of the Geological Survey.

MR. DAVID LANDEN: Few undertakings in exploration through mapping have contributed so much geographic knowledge as the trimetrogon photographic and compilation systems.

Just before the Second World War there was no practical means of producing

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accurate world aeronautical charts other than that of compilation from existing source material. An evaluation of the mapped land areas of the world revealed that 85% of the existing material was not even satisfactory for compiling at one to a million scale. So much of the information was so hazardous or wholly lacking that it presented a grave threat to air transport. Our military aviation struggled to find global air routes over areas which were for the most part unknown and unmapped or unblessed with control.

Oblique photography, with its tremendous horizon coverage, soon thrust itself upon the scene, for obtaining authentic terrain information from the air.

In 1937, the Geological Survey built a photoalidade from the design of R. M. Wilson for the original purpose of using oblique aerial or terrestrial photographs for topographic mapping. This machine was the only one of its kind possessed by the U. S. Government. It was by gravitation in 1941 that the Army Air Forces came to the Alaskan Branch of the Survey for assistance in developing a reconnaissance mapping method for use in compiling aeronautical charts.

The Photoalidade not only played a large part in the development of the Trimetrogon Method but soon proved itself to be a most practical means of obtaining topographic information from oblique photography. Some of the reasons are obvious. Photoalidade work is simply plane table mapping from the air, and is based on principles which are perhaps as old as the history of mapping itself. Through the medium of the oblique photograph, the photoalidade obtains horizontal and vertical angles which are used to locate the position and elevation of topographic features.

Horizontal and vertical angles are, of course, nothing new as most mapping methods, both ground and aerial, can ultimately be resolved into systems which utilize these angles as basic information. While the more highly developed and complex stereoscopic instruments automatically recover and make use of these angles in plotting, where these data are required in quantitative form for the solution of a problem, the ease and directness with which this information can be obtained by the photoalidade is most surprising. Even before Trimetrogon took shape into a complete system, the photoalidade was used as a means to translate oblique photographs into these angles and thus tie together the two obliques with the vertical to form a coherent system for radial line plotting.

The photoalidade, a bundle of metal arms, and a sketchmaster made of wood were the first tools in the enterprise. Many years experience in reconnaissance mapping, faith in the fundamental principles of surveying and a little experience in photoalidade work by the Alaskan Branch were the sole guides in breaking a new track in unmapped areas. Little charity was forthcoming if it did not work. It worked. It continued to work so that by 1943 there appeared in a little known manual on "Trimetrogon Mapping" the words "this form of mapping can well be the key which will unlock the last unexplored areas on the earth."

A profound contribution to the topographic knowledge of the world has been made by the Survey's small group of photoalidade experts. About 34,000 square miles of 100-foot and 200-foot contouring, 200,000 square miles of 500-foot contouring and nearly 2,000,000 square miles of 1,000-foot contouring have been completed.

In addition to this original work, about 6,000,000 square miles of existing topographic data was recompiled, verified and improved by use of the photoalidade. Some of the last unmapped areas of the world are now being uncovered by the use of trimetrogon in the Antarctic in 1947 and its present use there by Commander Ronne's Expedition at Marguerite Bay.

The process of creating topographic maps by means of the photoalidade can be briefly illustrated. A radial line plot is made with slotted metal arms and is tied to horizontal control. A network of detail points is located by intersections and planimetric detail is added by sketchmasters. This base is then photographically reduced to a convenient scale for photoalidade work, usually 1:250,000 scale, although scales up to 1:48,000 have been used for more detailed work.

The topographer studies the existing vertical control within the area and selects those trimetrogon flights which make the most efficient use of vertical control. In uncontrolled areas a start is made outside the area with some known points of elevation, bridging to obtain new elevations in the uncontrolled regions.

A pair of photographs which look into the area is selected and the vertical control is identified and marked on the obliques using a stereoscope to help locate the control points. Photoalidade work is always done with pairs of photographs since at least two horizontal rays must be used to intersect and locate each topographic feature.

Tentative values of tilt and swing of the photographs must be determined so that the photograph can be placed in the machine for a leveling-up procedure. These tentative values are obtained from measurements to the apparent horizon and are usually not sufficiently accurate because of the difficulty in selecting the correct apparent horizon. On the average, with good conditions, tilt can be predicted to within 30 minutes and swing within 15 minutes of arc from apparent horizon measurements. However, this is not an important consideration since the final tilt and swing are obtainable from ground control. To the computed tilt value obtained from horizon measurement is added a dip angle which represents the angle in degrees and minutes between the true horizon and apparent horizon. The dip angle varies for values of flying height and for all practical purposes may be computed in minutes of arc by obtaining the square root of the elevation of the camera above the ground. For this purpose the altitude of the camera is considered to be its height above the terrain at the apparent horizon. The plate is set to the focal length. Having obtained tentative values of tilt and swing, the photograph is mounted on the plate of the photoalidade so that the apparent horizon is level. The tentative tilt angle is set into the telescope and the plate raised or lowered until the principal point of the photograph coincides with the crosshairs of the telescope.

Now the photoalidade operator is ready to draw horizontal rays to the control points. A sheet of transparent paper is placed under the machine with the ruling arm locked to the telescope. The control points, one at a time, are sighted with the telescope and penciled rays are drawn upon the templet at the edge of the ruling arm. At the same time vertical angles to vertical control points are read in degrees and minutes and are recorded. The photograph is now removed and a second photograph looking into the same terrain from a different viewpoint is placed in the machine. The process is repeated. A second templet containing horizontal rays is obtained and a second set of vertical angles to the identical control is read and recorded.

The two paper templets are now combined over the planimetric base resecting the plumb point and obtaining the best overall fit to the vertical control. Not all the rays will pass exactly through all the control since tentative values of tilt and swing have been used. Intersections are formed, however, so that ground distances can be measured from each of the plumb points.

Treating each control point separately, the tangent of the vertical angle is multiplied by the measured ground distance to obtain a difference of elevation. A correction for curvature of the earth and refraction of light is applied to the difference of elevation. The effect of this curvature always increases the difference of elevation so that the C and R correction, as it is called, is always subtracted from the observed difference of elevation. The corrected difference of elevation is now added to the elevation of the control point obtaining independent values of flying height.

Here the analogy to similar methods in ground surveying departs. In ground surveying, the earth is of course fixed, and a level bubble is contained within the surveying instrument which provides a definite and known horizon from which true vertical angles are readily observed.

The oblique photograph taken from the air presents no such happy state of affairs. In fact not only is the true horizon not discernible but all the five elements of orientation: tilt, swing, bearing, plumbpoint position and flying height are approximations. The independent values of flying heights, however, provide information from which the approximations are refined into accurate values in leveling up the photograph. At first glance the values of flying height present a complicated pattern. Some are higher than others, some are lower and some values may even agree. On closer inspection they fall into a recognizable and orderly pattern, when considered to form an imaginary sloped surface containing the various values of flying height.

Small changes in vertical angle are made to distant points and the photograph is rotated about its principal point so that the control on both sides of the principal plane yields equal values of flying height. Similarly both near and far points are adjusted by a tilt change in the photograph to yield equal values of flying height. The result is that when vertical control is observed for a second time with new values of tilt and swing, independent values of flying height now agree within very close limits. This system of leveling the oblique photograph is based on a very simple premise—that the photograph has but one flying height. Successive tilt and swing corrections are made to obtain the correct flying height, and a level reference plane is formed from which the elevations of unknown points can be determined.

There are many variations of this method. When a correct flying height is found for one photograph the other can be quickly leveled by assuming its flying height to be the same. The ground distances are used to compute vertical angles for two distant points. The two photopoints are then made to coincide with the computed vertical angles and the leveling up procedure for all practical purposes is complete.

Another method particularly useful when the compilation lacks sufficient horizontal control to provide accurate resections is known as the "butting" technique. It has been used in the mapping of islands or areas where shore line is visible and has produced satisfactory maps where no additional information but flying height and focal length are known. Vertical angles to shoreline points are read and recorded, using approximate value of tilt and swing for the photographs. This time, the ground distances are computed, using the altimeter height of the airplane. The ground distances are then plotted along the horizontal rays and the templets are combined holding to the near water points. The distant plotted points do not usually coincide, because of the tentative values of tilt and swing, but intersections are formed which yield independent values of flying height. The photographs are then leveled up to a more accurate tilt and swing, and new ground distances are computed and plotted along the rays. When combined, the final paper templets represent a rectified version of the oblique photographs with the plotted points in orthographic position. While this last method is extreme, in the sense that elevations depend on the ratio of the assumed to the exact flying height, it give excellent results when horizontal control is available to establish scale and to obtain accurate values of flying height.

After the leveling process is complete, elevations are obtained with comparative ease. Additional points, whose elevations are to be determined, are selected on both photographs and additional rays are drawn on the templets. The vertical angles are read and recorded. The paper templets are again combined providing ground distances to the intersections. For rapid computing a modified slide rule is used. With a setting for vertical angle and ground distance, the difference of elevation is obtained. This value is corrected for curvature and refraction and subtracted from the flying height to obtain the elevation. As many elevations are obtained as are necessary to control the area for topographic sketching. Here the tremendous reach of the oblique photograph makes its most valuable contribution. Working well past the zone which limits the planimetric work, elevations are obtained over a much larger area. A single pair of photographs, worked for distant elevations 50 miles and more away, can provide elevations for an area of one thousand square miles.

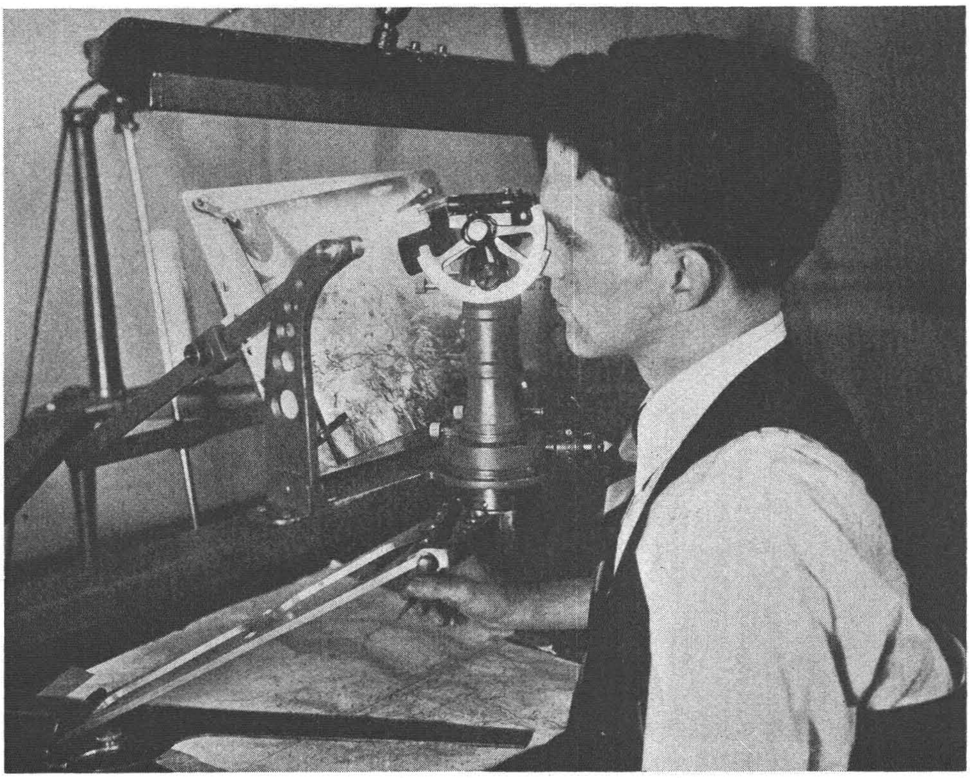

FIG. 1. Topographic mapping with an early model Wilson Photoalidade.

Topographic sketching is the last and final phase. In this work the "close up" photography is studied under the stereoscope as a guide in the sketching of contours. These flights give a detailed view into the terrain although they may not have been used in the photoalidade. The shape and relief of the terrain is portrayed by contour lines, interpolating the contour intervals between points of known elevation.

Contours are at 250, 500, or 1,000 foot intervals, depending on the relief

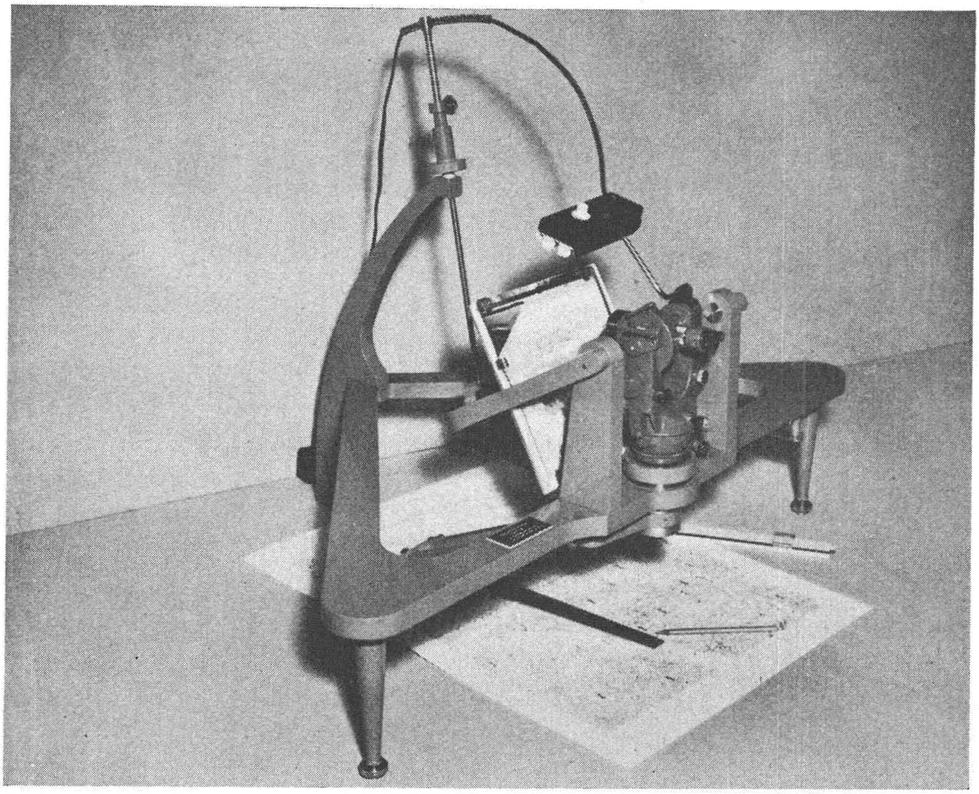

FIG. 2. New 1948 Model, U. S. Geological Survey Photoalidade with Wild T-1 theodolite.

of the ground and the scale of the required map. This terrain information is later accentuated with layer tints and colors so that it can be quickly read.

In 1943 a new use for the Photoalidade was found for the determination of elevations from vertical photographs. The vertical photograph is placed on the plate ninety degrees from its horizontal position so that the surface of the table becomes a vertical plane. The lateral tilt is set in the machine by raising or lowering the plate. Tip is set by means of the angular relation between telescope and blade. The optical axis of the telescope represents a plumb line piercing the photograph through the plumb point. The intersection of vertical rays drawn with the ruling edge of the blade determines the elevation of the feature. A double photoalidade with two plateholders and telescopes has been used advantageously in obtaining elevations directly from pairs of vertical photographs.

A new photoalidade has been built by the Division of Field Equipment of the Geological Survey and is on display at this meeting, for the first time. This instrument is the result of many studied improvements suggested by members of the Geological Survey. It has been radically simplified and uses fewer parts than the old model. The precision built frame and plate holding assembly have been built out of a solid slab of aluminum one inch thick.

Replacing the old telescopic alidade is a Wild Model T-1 theodolite which reads to one minute of arc and can be interpolated to read to one-tenth of a minute of arc. A horizontal arc within the theodolite is now available as an alternate to the ruling arm for photo triangulation using ground photography.

The swing plate which holds the photograph is now made to rotate about the principal point and is controlled with a slow motion adjustment. Changes of tilt are more readily made from a tilt adjusting screw within easy reach. The tripod can be leveled up by means of adjustable screws on the tripod legs while observing a level bubble in the base of the theodolite.

The horizontal system is capable of producing more accurate horizontal rays by using a magnesium alloy crossarm which provides greater strength and rigidity for the ruling arm. Even the lighting system has not been overlooked since the new instrument carries built-in fluorescent tubes for observing the photograph.

With the new Photoalidade a greater opportunity is present for increased accuracy, particularly in larger scale work. Further development will be carried out in the extension of horizontal and vertical control from oblique photography. This control may be used in conjunction with stereoscopic plotting instruments which utilize vertical photographs.

PRESIDENT SANDERS: Thank you, Mr. Landen.

Now we come to our last speaker of the afternoon, who will be followed by the movie referred to earlier. We have for our next speaker Mr. Sidney A. Tischler, Assistant Chief of the Photogrammetry Division of the Aeronautical Chart Service.

Mr. Tischler is a good example of the excellent work being done at Syracuse University by Professor Church. He is from that school and has had his practical experience in the Aeronautical Chart Service. During the war he was overseas in this work with the rank of major.

We will now hear from Mr. Tischler on the subject of the "Procedural Developments in Trimetrogon Compilation."