MR. SIDNEY A. TISCHLER: Approximately seven years ago, the basic techniques required for photogrammetric compilation from trimetrogon photography were developed to meet the pressing demands of global warfare for improved aeronautical charts. Since the beginning of the charting program, the U. S. Air Force has accomplished over 16 million square miles of trimetrogon photography, of which approximately 70% has been compiled and incorporated in aeronautical charts covering areas throughout the world.

Photogrammetric compilation for this program is currently being accomplished for the Aeronautical Chart Service by two separate operating facilities; one being the Trimetrogon Section of the Topographic Branch of the U. S. Geological Survey, and the other, the Photogrammetry Branch of the Aeronautical Chart Plant, located in St. Louis, Missouri. The latter organization is the operating installation of the Chart Service.

The general procedures followed for trimetrogon compilation have previously been presented to the Society, and considering the comparatively short period of time over which the method has been in use, are well known by photogrammetrists. It is the purpose of this discussion, to present those features of the compilation process which have been developed to meet increased standards of accuracy and completeness for small scale photogrammetric compilations from trimetrogon photography.

The compilation program is scheduled in alignment with the Chart Service Maintenance Schedule for the 1:1,000,000 World Aeronautical Chart Series. The maintenance schedule is a plan whereby each chart in the series is reviewed for possible recompilation or revision at least once each three years. Those charts in frequent use are reviewed once each year, with charts of lesser demand being reviewed every two or three years. This schedule is based on a 12 month period of time for chart compilation, which will include research, compilation from map sources, drafting and reproduction. In order for adequate base material to be available in time for chart compilation in areas of trimetrogon coverage, it is necessary to establish a photogrammetric program which will anticipate maintenance requirements by at least six months.

The photogrammetric compilation schedule is prepared on an individual chart basis, and will include charts requiring revision of existing trimetrogon compilation, in addition to chart areas for which initial compilation must be prepared. Charts incorporating trimetrogon compilations performed during the war years under adverse conditions, are being revised to meet current compilation standards and specifications as rapidly as production capabilities permit. Current rate of photogrammetric compilation for the Chart Service is approximately 100,000 square miles per month of original compilation, and 125,000 square miles per month of revision work.

Important to maximum and proper use of the photography is the policy of of complete chart compilation followed by the Photogrammetry Division. This policy establishes the extent and form of the compilation. Where 50% or more of a 1:1,000,000 scale chart is covered by photography, compilation of the entire chart becomes a responsibility of the Photogrammetry Division, using existing map information for areas not covered by photography. Where less than 50% coverage is available, responsibility includes only the area of photo coverage properly joined to existing map information. The completed compilation is termed a photogrammetric base, and is designed to serve as a compilation base from which color separation draftings may be prepared for production of the lithographed chart. It is drafted on metal mounted paper, and is the same as the

standard aeronautical chart with respect to scale, symbols, and drafting specifications.

In addition to the photogrammetric base, a separate chart series designated as the Air Force Preliminary Base Chart, is also produced under the photogrammetric program. These charts are prepared as a record of photogrammetric compilation performed, and are published at a scale larger than the standard aeronautical chart currently maintained for the area. The AF Preliminary Base Chart is reproduced as a monochrome lithographed edition, at a scale of either 1:500,000 or 1:250,000, and generally contains more detail than would be incorporated in an aeronautical chart of the same scale. All work on these charts, including final drafting and the preparation of a reproduction negative, is performed by the compiling units of the Photogrammetry Division. These charts are generally available to the user within 30 days after completion of final drafting. Use of halftone in conjunction with standard mapping symbols, renders these charts highly legible, even though reproduction is in monochrome. Preliminary base charts are filling the requirement for a small scale all purpose chart in areas otherwise devoid of reliable map information.

In order that a policy of complete chart compilation may be successfully followed, it is necessary that the compiler be furnished existing source material for the compilation of areas either entirely lacking in photographic coverage, or where a too wide spacing in flight lines makes interpretation of photography uncertain. The Research-Library Division of the Chart Service fills this requirement by collecting and evaluating all available information existing for the chart area which may be of aid to the compiler. This will consist not only of large and small scale maps, but also of intelligence data, travel guides, road classification data, surveys by private commercial concerns, population figures, books concerning the geography and geology of the area, and any other information that may assist the compiler to chart the area accurately, or to interpret the photography correctly. The Research-Library Division is also responsble for the furnishing of all geographic control information available for the area. Collection of this information is performed largely through the facilities of the Army Map Service.

Source material and control collected, is evaluated for reliability and forwarded with recommendations as to its use to the compiling unit. Final decisions as to the use of this material in areas of photo coverage, rests with the compiler, who is often in a better position to determine the reliability of existing information by being able to make comparisons with photographs for portions of a map or map series.

With photography, source material and control available, the initial steps involving photo-identification of control, selection of radial control points, and templet assembly, are basically similar to the methods used in large scale mapping. Certain differences however do exist. Only a small portion of the geographic control is furnished in identified form. In most cases, photo-identification must be preceded by plotting of the control on the largest scale map available, preferably a map which utilized the control in its compilation. Control falling on features identifiable on the photography may then be transferred and utilized in the assembly. Selection of radial control points on oblique photographs, particularly those points which must be common to facing obliques, is a skill requiring greater interpretive ability than ordinarily required for vertical photography.

The effect of tilt and mechanical errors on the positions established in the templet plot has been the subject of several tests by the Photogrammetry Divi-

sion. Methods of determining tilts for trimetrogon photographs have been developed to the point where reasonably accurate results are obtained. The use of such tilt values in the compilation procedure, is based on the separate effects of tilt on planimetric position, and on topographic determinations performed with the photoalidade or topographic angulator.

In general, it has been concluded that with respect to planimetric position, mechanical deficiencies in certain equipment result in errors that are of greater significance than any error that may be introduced through use of templets which do not reflect the precise tilt, at least for photography having an average tilt of three degrees and a maximum of five degrees, over areas of moderate topographic relief. Where it is necessary to perform original topographic work requiring measurement of ground distances from the nadir point as established on the planimetric base, it is recognized that any improvement in nadir point position will be of value in the determination of elevations.

Where only a minimum amount of original topographic work is to be performed, current methods are to establish correct interlocking relationships between the three photographs of the trimetrogon assembly, and to compute individual tilts at spaced intervals through the flight. Tilts for intervening exposures are checked from the position of the horizon on an oblique exposure, assuming no change in the interlocking relationships of the cameras during the flight.

Preparation of the templet is then based on the average tilt value of the flight, with individual tilts being used where allowable deviations from the average are exceeded. Use of the average tilt permits a constant setting of adjustments for the rectoblique plotter, and also permits the plotting of the nadir point by means of a templet rather than individual measurements on each photograph.

In areas where extensive original topographic work is required, a more accurate location of the plumb point is desired. In preparing the planimetric base for these areas, individual tilts are used for the plotting of plumb points, and for preparation of the metal templets. While an improvement in ground distances measured from the plumb point is obtained through this procedure, it is not entirely satisfactory for photoalidade operation.

Improvements in the design and construction of both the rectoblique plotter and the metal templet are being made, and when placed in operation may serve to reduce mechanical errors to a point where a significant improvement in the base for topographic determinations may be obtained by using accurate tilt values.

In extending the radial control net, one distinct advantage of the high oblique photographs of the trimetrogon system is made obvious. Where a particular flight or portion of a flight deviates greatly from adjacent flights, a complete break in the control net does not occur, as long as common points may be selected on the facing obliques. Tie points separated by as much as fifty miles may be identified on flights of good photographic quality. Ability to delineate detail in these areas will be decreased, but the main scheme of control is not broken. Assembly of the radial plot includes use of alternate exposures only, with scale being maintained through a combination of the verticals and obliques.

While an accurate and adequate control net is of significance and importance to the photogrammetrist or cartographer, the aerial navigator or other user will usually judge the quality of the chart in accordance with the selection and manner of representation of the detail thereon. In preparing compilations of areas throughout the world, it has been necessary to evaluate the significant features of many varied types of terrain, in order to present a consistent por-

trayal of identifiable ground features on the aeronautical chart. In many areas of the world, features normally accepted for representation are either entirely lacking, or become relatively unimportant in comparison with other terrain characteristics. This is particularly true in arid areas where parallel rock strata, domes, lava deposits, low ridges, sand dune patterns, alluvial fans, light and dark areas, etc., form the outstanding landmark features. Insofar as possible, using standard cartographic symbols, outstanding features of this type are selected and incorporated in the compilation in areas where they exist.

An important aid in the selection of these features, and in fact to the entire process of detail selection, is the similarity between the pilot or navigator's view of the terrain, and the oblique trimetrogon photographs. Features which appear prominent on an oblique aerial photograph, will invariably be important to the navigator or pilot as checkpoints along the flight path.

To achieve this end, selection of detail is often preceded by a layout of the oblique photographs for a large area, in order to establish the relative importance of the various terrain features by preliminary inspection. An initial evaluation of this type is a supervisory operation, and is performed by skilled personnel having knowledge not only of characteristic land forms, but also having the experience to determine from the comparatively large scale photography, those features which will be important to a chart at 1:250,000 or 1:500,000 scale.

The sound and accurate initial determination for detail selection, which will eliminate excessive deletions for the reduced scales, or the need for additional sketching in the proofreading and editing stages, is an important factor in establishing the cost and overall value of the compilation.

Actual delineation of the photographs in colored inks, is accompanied by constant reference to existing map information, as an aid to photo interpretation in the distant areas of the oblique photographs. Comparison of photographs with source material at this stage of compilation will also either verify or disprove the existence of features shown on previously prepared maps, and serve as an initial evaluation of source material for use in final editing procedures.

In connection with the selection and representation of terrain features from photographs for aeronautical charting, considerable experimental work has been performed by the Chart Service on the production of the "shaded relief chart." This type of chart shows terrain as an artist portrays it when aerial photography is the basis of representation. Accepted cartographic symbols leave much to be desired in the expression of those features which form only patterns of light and dark areas, or consist of an unusual ground texture, but which, however, are important landmarks when viewed from the air. In some areas, these features are much more prominent than those normally accepted for symbolized representation.

Classification and adoption of symbols to portray correctly these types of features, would be a near impossible task in addition to complicating the problem of chart interpretation for the average user. A few aeronautical charts of the shaded relief type, produced from aerial photography, are currently being distributed by the Aeronautical Chart Service.[1]

Transformation of the oblique photograph, and sketching on the acetate base, is performed through use of the oblique sketchmaster. This instrument, which was designed especially for the trimetrogon compilation process, has many

[1] Kingstey, R. H. and Holmes, H. C., *Terrain Representation from Aerial Photographs for Aeronautical Charts;* and Mundine, J. E., and Shelton, Hal., *Visual Topography,* PHOTOGRAMMETRIC ENGINEERING, Vol. XI, No. 4, pp. 267–278, Dec. 1945.

advantageous features for small scale compilation which are frequently overlooked.

The sketchmaster is an inexpensive, light weight, portable, and easily maintained instrument, which occupies about one square foot of table space. Its operation requires no darkroom or otherwise specially prepared working space. It utilizes contact prints which can be prepared in photographic laboratories having only standard contact printing equipment. Competent operators for this instrument can be developed from personnel having no previous photogrammetric experience, within a maximum period of 30 days. With proper illumination of the photograph, use of the sketchmaster involves no more eyestrain than many other optical plotting instruments currently in use. Orientation of the photograph to the base, correcting for tilt and flying height changes, is accomplished in only a very few minutes. Adjustments for relief displacements are made without disturbing the orientation of the photograph. Ability to view and sketch detail from the photograph, is limited only by the photographic quality of the print, and the distance the operator is able to reach from the aperture.

While the current basic design of the sketchmaster has been adequate for transforming and sketching from trimetrogon oblique photographs, for use in compilations at 1:250,000 and smaller, there is a recognized need for a plotting instrument capable of performing similar work for use in medium scale compilations of 1:200,000 and larger. Development of such an instrument to fill the existing gap between the sketchmaster and the oblique multiplex has been requested by Aeronautical Chart Service.

Sketching of detail on the base manuscript, generally at 1:80,000 scale, is followed by a proofreading procedure, which again utilizes photographs and source material for the primary purpose of checking photo interpretation, accuracy of sketching, and continuity of detail.

In some instances involving areas of inadequate photo coverage, where the source material is at medium or large scales, and is considered reliable for the features shown, supplementary detail is added by reducing or enlarging the map to the manuscript scale, and tracing directly on the acetate base. In most cases, however, where only small scale charts are available, the incorporation of supplementary detail is performed at a later stage after the compilation has been reduced to the 1:250,000 or 1:500,000 scale.

Planimetry shown on the manuscript is inspected for character of detail considered important at the largest publication scale, and corrections made where a too generalized interpretation has been performed. Deletion of obviously unnecessary detail is also performed by the proofreader. However, it is preferred at this stage that the manuscript carry a slight excess of detail rather than be deficient in this respect. As detail on the manuscript is verified and accepted, inking is performed by the poofreader, both as a record of features checked, and in order to eliminate the possibility of unjustified generalization which might take place in a separate inking operation.

The inked manuscript is then reduced by photography to either the 1:250,000 or 1:500,000 scale, depending upon established requirements for preliminary base charts. Copies of the compilation, either in the form of transparent positives or white back acetate prints, are furnished for use in subsequent phases of the work.

Inasmuch as the photogrammetric compilation will in most areas replace previously published small scale charts, and possibly larger scale mapping, it is necessary to justify all changes made in the photo compilation with respect to existing map information. Justification for changes in shape or alignment, the

deletion of previously mapped detail, and the inclusion of new detail, is determined by a photo-editing procedure, wherein all features appearing on the reduced copy of the compilation are verified and selected by re-inspection of the photography. The omission from the compilation of previously mapped detail, which would normally be shown at the compilation scale, must be substantiated by the photo-edit. In areas of intense culture, where numerous maps or charts of questionable reliability exist, the photo-editing procedure becomes a difficult and detailed task.

While only that control capable of being identified on the photographs can be used in the radial control net, identification and use of other control becomes practical at the reduced scale. Surveys locating ridge tops, streams and other natural features, or trigonometric stations located in small towns which could not be previously identified may now be incorporated in the compilation in areas where additional control is considered desirable.

In performing this operation the procedure followed is to plot the additional control on a compilation base according to its geographic position. Each control point so plotted will also be located according to its description on the reduced copy of the manuscript base. A process of area adjustment is then made by dividing large areas into many smaller areas, and shifting detail by successive small scale changes through use of a reflecting projector. In this manner, changes in position may be made without causing a shear in detail, or noticeable change in shape or alignment. Long range planning of control requirements, and a more thorough research of existing control than was possible during the war years, has eliminated to a large extent the necessity for this type of adjustment.

Perhaps the most difficult work of the entire compilation occurs where it becomes necessary to join the photo compilation to source material of poor quality. Evaluation of existing maps and charts performed during previous operations, will indicate the most reliable material to be used in effecting the join. A general policy established for this work, is to extend the photo compilation by sketching detail from the distant portions of the oblique photographs, until comparable reliability between sketched detail and map detail may be assumed. Similar detail is then identified and joined, with adjustments in position being made in accordance with the best information available. With the photo compilation joined to the best existing map information, the remaining chart area is compiled from source material, where the photo coverage is at least 50% of the area of the chart. Where less than 50% coverage is available, the Photogrammetry Division is responsible for only the area of photo coverage properly joined to the most reliable existing map material.

Names for the various features appearing on the compilation base are selected from the source material, and generally in accordance with instructions furnished by the Research-Library Division of the Chart Service. Where conflicting information exists, decisions of the Board on Geographical Names of the U. S. Department of Interior are accepted as final.

Inasmuch as the method for determining topographic information has been treated as a separate subject by Mr. Landen in his paper on "Reconnaissance Mapping with the Photoalidade," references to that portion of the compilation procedure have been omitted. Contour information and spot elevations provided by the Photo-Topography Units, are transferred to the compilation base, which is then complete with respect to planimetric and topographic detail.

Final draftings for the preliminary base charts are prepared from the compilation base on either Dyrite, or topo base acetate suitably conditioned. Inasmuch as the final draftings are at reproduction scale on a translucent medium

contact methods, instead of the more commonly used projection methods, are used for the preparation of the reproduction negative. The original selection of this method was influenced to some extent by the lack of camera facilities during the war years, but has since proven so satisfactory that it has been maintained in current use for the preparation of preliminary base charts.

Best results in the use of this method, have been obtained by preparing two separate drafting plates for detail appearing in black on the Preliminary Base, in addition to a third for detail to be shown in halftone. One black plate will contain all type and marginal information for which a printers ink has been used. The second black plate will contain all drafted lines. Separate contact negatives are prepared for the two black plates in order to accommodate the difference in opaqueness between the two inks used, without sacrificing line values or negative quality of either plate. Corresponding film positives are then prepared from the negatives, using a line screen with the negative containing the detail to be shown in halftone on the preliminary base chart. The film positives are then combined in accurate register and are used to produce a single negative for lithographic reproduction.

Preparation of the photogrammetric base is preceded by the deletion of detail from the 1:250,000 or 1:500,000 compilation base. In most instances, trails, secondary roads, minor drainage, and small towns and villages, are deleted to achieve the desired detail density. This work is performed on a basis of photo inspection, in order that features most prominent from the air may be retained.

Initial drafting of the photogrammetric base is performed in non-photographic blue pencil from the compilation base, on metal mounted drafting paper, using a reflecting projector to make the required scale reduction. The penciled base, at the final reproduction scale of 1:1,000,000 or 1:500,000, is then inked in standard colors, using the same symbols and drafting specifications established for the printed aeronautical chart.

Where the entire chart area has been compiled by the Photogrammetry Division, the base is then ready for color separation drafting and other work incidental to reproduction as a standard gradient tinted chart. Where only a partial photogrammetric base has been prepared, the partial base and source material is furnished a contracting agency of the Chart Service, for compilation of the remaining area of the chart.

Upon completion of a photogrammetric base, it is required that the compiling unit furnish a compilation history covering all phases of the work involved in preparation of the base. The compilation history will include an evaluation of existing maps furnished as source material, a description of the methods used in performing joins between map and photo detail, identification of maps used to effect joins and to complete chart areas, control used in templet assembly and in later adjustments, and other information relating to the use of photography, control or source material in the compilation.

Inasmuch as a particular chart may consist of varying degrees of reliability, depending upon extent of photo compilation, availability of geographic control, and quality of source material other than photography, the compilation history serves as an evaluation record upon which future decisions in connection with the maintenance of the chart may be based.

The cost and man hours required for trimetrogon compilation at a particular scale, will be dependent upon the type of terrain being charted, extent of photo coverage, density of culture, and the amount and quality of previous mapping or charting in the area. Preparation of a preliminary base chart will cost approximately $0.90 per square mile for 1:250,000 scale compilation, and $0.25 per

square mile for the 1:500,000 scale. These cost figures do not include the expense involved in accomplishing the photography, or processing of aerial film and contact prints.

It is of interest to note that whereas in large scale photogrammetric mapping, the cost of photography is small in comparison with the cost of compilation, the reverse is true for small scale charting from trimetrogon photography. Because of the low cost of compilation, it is economically practical in particular areas, to make available to the user such improvements in charting detail as may be obtained from photography generally considered inadequate, with the consideration of recompilation as better photography is accomplished.

Also included in the effort to have current charts contain the latest available information, is the procedure of using the photo compilation in the base manuscript stage, for correction of detail on the existing chart which may be considered hazardous to air navigation. Where such detail is discovered, action is taken by the Chart Service to overprint existing base stock with corrective information to serve until the new chart is available.

While procedures described in this discussion would be simplified by the use of small scale verticals, the advantage of 180 degree coverage afforded by the trimetrogon obliques is a factor which should be given full value. This feature, which permits flight line spacing of 25 miles or more, is largely responsible for the extensive photographic coverage now available for intelligence and geographical studies, in addition to small scale mapping. Trimetrogon photography accomplished by the Air Forces has furnished a maximum amount of coverage with respect to flying time utilized. If it had been attempted during the past seven years to secure vertical photography for small scale mapping with the same number of Air Force units, less than 20% of the present coverage would be now available.

Flexibility of the compilation procedures, has made possible the use of photography accomplished under combat conditions, where only minimum limitations were placed on the pilot as to position and direction of the flight line. Trimetrogon photography is currently being accomplished in accordance with more detailed specifications now practical under peacetime conditions, and is consequently of higher quality and more easily compiled.

The extensive photo coverage provided by the Air Forces with the trimetrogon system, and the utilization of this photography through photogrammetric compilation methods, is resulting in the availability of improved aeronautical charts, which more adequately meet current navigational requirements for worldwide air transport.

PRESIDENT SANDERS: Thank you, Mr. Tischler.

Before introducing the next item, which is not on the program, I would like to call your attention to the work being done by Mr. Bob Sterling, who is our official photographer gratis. Anyone who wants any special photographs that have been taken either of themselves or of something of interest to them should contact the Secretary-Treasurer.

The Corps of Engineers, specifically the Engineering Board, down at Fort Belvoir, Virginia, always has a habit of coming through to make a good thing better. We have had a good meeting here today, but the Corps of Engineers insist on making it still better. They have brought to us a film on the helicopter. I do not know any details about it, so I am asking one of our members, Mr. William Cude, who is on the Engineering Board and who is in charge of surveying, mapping and photogrammetric work at that establishment, to come up here and give a brief introduction to this film. Mr. Cude.

MR. WILLIAM C. CUDE: Mr. President, Fellow Members, Ladies and Gentle-

men: I think that first I had better set Mr. Sanders straight on the name. We were very glad to have our name changed to the Engineering Research and Development Laboratories and to get away from the old name of Engineering Board, since a number of people, probably at times, insisted on spelling it b-o-r-e-d.

I know the time is getting late, so I only want to give you a very brief history of the project of extending ground control by the use of helicopters so as to give you a little better idea of the film.

An idea originated with a Captain R. Cooper while he was with us at the Research and Development Laboratories during the war. He used an Autogiro to gain information by air photography under combat conditions. The idea was to take the giro, fly around over enemy lines and get pictures, and have some setup so that if he were attacked, he would jettison the vertical prop, and by means of excessive power, be able to duck back to friendly land with his information. For a number of reasons, that idea was discarded as not being practical.

After the war, however, Captain Cooper and myself happened to be in Japan, and he brought the matter up again. We discussed it with General Loper, who was charged with covering rather vast areas of inaccessible areas with maps. He felt it worthy of investigation.

On my return to the laboratories, a project was assigned to the Engineering Research and Development Laboratories to investigate the feasibility of using the helicopter for extending ground control.

The Air Forces cooperated by including in their investigations a study of the serviceability of the R5A helicopter, a project to try out this method with the engineers. Mr. Ransford McGregor was assigned as project engineer for the Research and Development Laboratories. Maj. Frank Ledbeter, of the Air Proving Ground Command, was the project engineer for the Air Forces. I cannot list all of the personnel who helped on this project, but I can say that practically every member of our Topographic Department at Fort Belvoir, as well as our branch at Wright Field, worked on it. Also, the Mapping and Charting Branch of the Photographic Laboratory of the Air Materiel Command assisted us. The Engineering District at Little Rock, Arkansas, furnished both personnel and facilities. We were also assisted throughout the project by Colonel Colby, the Air Force liaison officer to the engineers who are stationed with us at Fort Belvoir.

One thing that is not shown in the film but which we know can be done is that all of the ground material can be carried by the helicopter, including towers in a piecemeal fashion, so that considerable areas could be covered for us by carrying this material in the helicopter.

A report has been prepared and is now being printed at the laboratories covering this project. The Air Proving Ground Command at Elgin Field have produced a report covering the Air Force phase.

I hope you will bear with us through this movie. Knowing that a number of people would like to see it, and that unless we rushed it, some of you would not have another opportunity, the boys in the motion picture laboratory worked overtime, ending up with an all-night session to try to get a work print for you. It is not in finished form in that the timing of the sound is not always entirely synchronized and the modulation is not always exactly what it should be. I can assure you that our narrator was not jumping back and forth from adolescence, but that is the way the sound worked. I hope you will enjoy it.

(The movie, "Helicopter Survey Methods for Mapping in Cooperation with the Department of the Air Force," Film No. 1319, was shown.)

[The meeting adjourned at four forty-five o'clock.]