Like all good executives, the commanding officer, Colonel W. H. Mills, has surrounded himself with capable men. He has brought with him to help carry the ball today one of the men we know well, a photogrammetrically minded assistant, Major Albert L. Nowicki. We know him particularly for his writings on the subject of stereoscopy.

I take great pleasure now in presenting to you Colonel Mills who will, in turn, introduce Major Nowicki. Colonel Mills.

COL. W. H. MILLS: Mr. President, Members of the Society, Ladies and Gentlemen: I have neither the ingenuity nor the intention of discussing the technical aspects of photogrammetry. That subject has been, and will be, much discussed here by more capable men. My experience with bridging, for example, has been over rivers or at the card table. So my status in this conference is that of an interested spectator. For I am intensely and officially interested in photogrammetry's application to military cartography. And I am cursed with a profound and *unofficial* curiosity.

Fighting men, even in peaceful years, have need of extremely accurate and detailed knowledge of all strategic areas. The practice of training an Army with wooden guns and obsolete maps belongs to history, we hope, along with chain mail and Roman cartograms. There are indications that the future satisfaction of such mapping needs rests largely with photogrammetric processes. The remark that the aerial camera was the Mata Hari of World War II is probably a colorful exaggeration. But there is no denying its important role in furnishing up-to-the-minute intelligence for both combat and construction planning. Nor is there cause to discount its importance in the postwar task of providing the maps this country so woefully needs.

Tremendous technical difficulties had to be overcome to permit the accurate plotting of maps from stereoscopic surveys. The solution to some of these problems is still a responsibility of the future. Sporadic battles are still waged among the experts about the relative value of favorite methods and equipment, but photogrammetric compilation, like radio and frozen foods, is probably here to stay. Technicians, who comprise societies such as this, can guarantee that the aerial photograph will be a continually improved instrument of communication for terrain intelligence. They can encourage the discovery of more rapid, more precise and more economical procedures. They can assure the United States of up-to-date, low-cost, large-scale topographic maps.

Various military authorities have remarked upon the relative ignorance in map language among the public, as evidenced by inductees during the past war. This lack of knowledge is not confined to an understanding of cartographic expression. It extends to an almost general ignorance of map purposes and map procurement. Government agencies have tried since the war, to correct this condition by establishing map information offices and by issuing notices of items generally available. Associations like yours can do much along similar lines to educate the layman who needs a good map and just doesn't know how or where to ask for it. There is a tendency in scientific societies to confine discussion of their interests almost exclusively to their membership. This is a commendable practice when it pertains to the aspects of the membership's specialized activities. But it seems to me some informal and informative campaign could be devised which would serve two purposes—blow the air of mystery from cartographic procedures—and enlighten the public on the types of maps being published in this country, their purpose and the channels for their distribution.

Military cartographers are continually trying to extend the application of aerial photography beyond its customary and accepted uses in topographic mapping. During and since World War II the emphasis on aerial photography as source material for mapping has increased with our program's scope and the development of photogrammetric techniques and photogrammetry occupies the enviable position of being expected to supply the medium for completing a large portion of these programs.

It is natural that man should take advantage of every opportunity to look at his earth from a different angle. It is just as natural that he should try to explain that difference graphically—by means of a map. So it was obvious that he would adapt the bird's-eye view of the aerial camera to his map making. The technical adaptation of photogrammetry, then, is a natural result of American inquisitiveness and acquisitiveness. But its use and development have brought us dangerously close to another American characteristic. We are prone to accept each discovery in a specific field of science or industry as a panacea. Our enthusiastic praise and almost complete acceptance of the sulfa drugs is a typical example. So I think we should carefully avoid considering photogrammetry as the cure-all or catch-all of cartography. It may, but so far has not, functioned in complete disregard of mapping's other phases. Future years may retire the surveyor to the comparative ease of arm chair computation, but probably not until he has taken a calibrated peek at most areas of the whole earth. There may come a time when the multiplex projector, the stereoplanigraph, or their yet undiscovered successor will produce a manuscript completely suitable for lithographic reproduction. Until that time photogrammetry will be a very important first phase in the construction of maps at the Army Map Service.

However, the photogrammetrist should maintain his opinion that mapping from aerial photography ranks at least third in human functions—being exceeded only by the efforts to satisfy hunger and reproduce the species.

That attitude of enthusiastic emphasis will insure the world of eventually being well portrayed. We do not think that we can map the world in a day. But we believe that photogrammetry's contribution to military mapping will shorten the days between that goal and the present.

Something of what we at AMS are doing and proposing in other fields of military cartography will be told to you by the next speaker, Major Nowicki.

MAJ. ALBERT L. NOWICKI: The past year has seen a number of changes in military mapping policy and trends. I wish to take a few minutes to review some of these changes and to point out some of the problems which still confront the military map maker.

It has been stated rather facetiously that there are three basic military axioms.

a. It always rains in war

b. It's always too cloudy to get aerial mapping photographs.

c. Battles are fought along military grid junctions.

Military strategists can do very little to alleviate the conditions expressed in the first two axioms. The latter axiom, however, deals with a condition which can be improved somewhat by proper planning, mainly by reducing the number of grid junctions throughout the world.

During World War II over 85 different military grid zones were established with separate grid junctions occurring on all four sides of each zone. A few of the grids were based on very precise map projections, such as the Lambert Conformal, or the Transverse Mercator projection. Unfortunately, the vast majority of grids, including those of the United States, were based on non-conformal projections such as the polyconic.

In all problems dealing with map projections and, hence, grids, it should be borne in mind that the exact physical shape of the earth is still unknown. Its shape is not that of a true sphere, but that of a slightly irregular spheroid. Added to this is the fact that different countries throughout the world have adopted different spheroids (or shapes of the earth) on which to base their geodetic triangulation and mapping work. For instance, in North America, map projections and geodetic control are based on the Clark's 1866 spheroid; in Germany, on the Bessel's; in Spain, on the Struve, etc.

With at least seven spheroids and 15 projections to choose from, it is apparent that over 100 possible choices are open to the map maker. The problem gets even further complicated when it is necessary to place a military referencing grid upon the map. In other words, it is possible to prepare a map on a given map projection and on a given spheroid and, at the same time, have the overlaying grid based on an entirely different projection and spheroid.

Grids are necessary on military maps in order to simplify as much as possible the problems of target designation and determination of range and azimuth. Experience has shown that the use of geographic coordinates (i.e., graticule values of the latitude and longitude) is too complicated and time-consuming. Very complex geodetic formulae are necessary in the computation of distances and azimuths by this method. Likewise, intricate fire control instruments would be needed which would have to be manned by personnel highly trained in advanced mathematics. In time of war such procedure would be prohibitive. The other alternative, therefore, is to adopt a system in which plane trigonometry can be employed in the solution of triangles.

Military grid accuracies which are greatly in excess of the accuracies for the most precise weapon using the grid appear to be neither necessary nor practicable. As a general rule, a suitable military grid should be one designed to conform to at least the minimum probable errors of permanently emplaced guns which are rarely less than 1/555 in range and 1/5,000 in deflection. It should be accurate enough for all weapons and all military uses other than for very long distance missiles, should be quickly applicable to any previously ungridded native map, should yield readily to simple computing methods, and should provide simple numerical designators for location of targets.

Closely allied to the problem of choosing the proper grid is the problem of choosing the proper linear unit to express that grid. Three general systems of linear measure are commonly encountered on maps and in grids: the metric system, the so-called English system, and the nautical system. Mixtures of these systems unfortunately are prevalent. This matter is further complicated by the fact that three different elements are involved—map quantities, grid quantities, and the quantities employed by the using arms and weapons. Still another factor that must be considered, especially now that military ground maps will carry hydrographic as well as topographic features, is the manner in which underwater depths are expressed. Underwater depths are generally expressed either in meters or in fathoms, although shoal-water depths may be also expressed in feet.

What steps are being taken by the military map makers to alleviate this complex condition? First, the shapes of the earth (spheroids) are being reduced to five in number. These include Clark's 1886, Clark's 1880, Hayford's, Bessel's, and Everest's spheroids. It is planned eventually to convert the native maps and geodetic data of all countries which are based on other spheroids to one of the above five spheroids depending on the relative position of the country concerned.

One large land area of the world which has been just recently adjusted to a single datum is that covering Central Europe. Over one-half million square miles of first-order triangulation work, some of which was originally established over 140 years ago, was recomputed through the application of least squares and the theory of probability. Such an adjustment results in positive assurance that the computed coordinates of any station regardless of the route taken to get to that station will be identical. Due to the presence of a large number of common astronomic and geodetic stations (i.e., Laplace stations) it has been possible to obtain a datum largely free from the deflections of the plumb line, or station error. Further steps were also taken to reduce all measured bases to the International Meter and to their proper length on the International (Hayford) Ellipsoid.

The Central European adjustment is a start but much has to be accomplished before the entire world can become adjusted to a common datum. Considerable assembly work, critical analysis, and processing of great quantities of geodetic data will have to be carried out. Unfortunately, complete data on all the main nets of the world are not available. For political and other reasons many nations have carried out their geodetic and mapping efforts entirely apart from those of their neighbors and have retained the results of their work under security classification.

With respect to grids, the United States Army has adopted a military grid system for the whole world based on the Transverse Mercator projection and measured in meters. Tables are being computed on the five different spheroids. Sixty grid zones, each six degrees wide in longitude with a one-degree overlap have been established. In latitude the zones run from 80° N. to 80° S. Accuracy of the Transverse Mercator grid at the outer edges of each zone will be about 1:1,200 which should easily satisfy the minimum requirements of the artillery. In the north and south polar areas, the Polar Stereographic grid will be used.

Conversion of existing maps to the new grid system will have to be progressive rather than instantaneous. The problem is further complicated by the fact that conversion will also have to be made (especially in the United States) to the newly adopted military scales of 1:25,000, 1:50,000 and 1:100,000. In either case priorities will be given to those maps covering military posts, camps, and stations in the United States, followed by maps falling in the strategic area of the United States and foreign countries.

In addition to the conversion of maps to the new scales and the printing of the new grid on those maps, it will be necessary to express all the geodetic control stations in the form of Transverse Mercator coordinates. In the United States alone this represents more than 350,000 conversions. To insure that these computations can be accomplished in a reasonable time, recourse is being made to the use of punch card, automatic electric computing machines. Advantages of the use of such equipment is that the work can be accomplished at about one-third the cost of hand computations and the tabulated results are free of copying errors.

Investigations are also being carried out as to the feasibility of using extremely high speed universal electronic computing machines in connection with geodetic data computations and datum conversions. Basic requirements of machines of this type are that they must be capable of accepting large quantities of data at high speed, carrying out any specified set of operations on these data, and recording the required answers with a minimum of human attention. Fundamentally, the machines must not only be able to store up numerical and alphabetical information but hundreds of sets of instructions as well so as to use that information in an almost endless variety of ways. These numerical data and instructions are recorded on reels of magnetic tape by means of a keyboard similar to a standard typewriter. Unique electrical pulse patterns representing digits to be stored are then circulated through the machine at a rate of more than a million per second. Control circuits cause the pulses to be combined as desired for classification or computation. Solutions are recorded on other tape reels and are then automatically typed on paper or stencils as desired. The magnetic tapes can be stored with the original data retained, or they can be erased and re-used as often as desired. Needless to say, the use of such machines would be a distinct asset to the military mapping effort.

The adoption of new grids and new map scales is only one small step in the solution of the over-all military map problem. The possibility of new methods of warfare involving long range firing and radio navigation must also be taken into consideration. Topographic maps must not only be tied together correctly to serve the needs of short range artillery fire (i.e., 15 to 20 miles) but must be tied together correctly with other maps perhaps thousands of miles away. A long-range missile does not recognize a datum junction or a grid junction line. Map positions at the beginning and end of the missile flight must be on the same datum, otherwise errors of range and azimuth will occur. Unfortunately, our present military maps cannot be used in this manner for two main reasons. First, a large number of sheets in remote areas are based on astronomic positions which may vary from the true geodetic position by several hundred feet—in rare cases by as much as a mile. Second, information is lacking on the precise size and shape of the earth.

In the first case the condition can be improved by linking many astronomic stations together with geodetic nets, or by the use of gravity data. In the second case, several methods can be used, such as conventional triangulation, flare triangulation, and Shoran. An additional method, namely, observation of the solar eclipses has been used several times in the past and may well be considered in the future. A number of expeditions were sent to South America and Africa on May 20, 1947 where attempts were made to determine the distance between the South American and African continents. A previous attempt had been made on July 9, 1945 at stations in Canada, Sweden, and Finland.

An eclipse of the sun occurs when the moon passes between the earth and the sun. Only from within a narrow band on the earth's surface can total eclipse be observed. As the observer moves away from this narrow band, less and less of the eclipse can be seen until a point is reached where the moon does not pass between the sun and the observer at all. Likewise, conditions occur where the moon is in direct line with the sun but is too small to cover the whole disk of the sun. A narrow ring, or "annulus," appears around the moon and the eclipse observed under these conditions is said to be "annular."

The observations used for this purpose are quite simple and do not require very complicated equipment. The eclipse is photographed at certain times called "contacts" by means of a 35 mm., single system, movie camera equipped with a telephoto lens (or astronomic objective) and sound registration. Automatic recordings on the camera sound tracks are made of amplified radio time signals. To provide for failure of the radio signals, chronographs are used and their times registered on the film as well.

During an "annular" eclipse, four distinct moments of contact between the edges (called limbs) of the sun and moon are observed. The first occurs when the moon just begins to nibble at the sun; the second, when the annulus is complete around the moon; the third, when the narrow ring is broken; and the fourth, when the moon finally passes off the sun's disk. In certain cases of annular eclipse it is possible for a total eclipse to occur over a small portion of the earth. The duration of contacts two and three in such cases will vary from about 30 seconds at one end of the path to zero at the point of total eclipse and again to about 30 seconds at the other extremity of the path of the eclipse.

The problem is complicated somewhat by the fact that the moon is not perfectly round due to the mountains and seas. Just before the annular ring is completed, a series of beads of light appear (the so-called Baily beads) which are bits of the sun shining through valleys of the moon. By timing the appearance and disappearance of these beads, it is possible to reconstruct the theoretically circular limb of the moon and compute the exact time of contact.

Knowing the differences of time of contact by observers at two different places on the earth along the path of the eclipse, it is possible to calculate the distance between those two places. The accuracy to which this distance can be computed is dependent on the accuracy with which we can compute the distance of the earth to the moon (called the lunar parallax). At present this distance is accurate only to about one part in 30,000. If the eclipse is observed at two points on the earth's surface whose true distance apart has been previously determined by precise ground surveys, it is possible to work this problem backwards and compute the lunar parallax very accurately and use the results for distances along other parts of the track of the eclipse. Thus, it would be possible to test any assumed shape of the earth by comparing the distances derived from the eclipse with the corresponding distances computed from the latitudes and longitudes of the observers' stations.

The degree of accuracy which can be expected by this method should be very high in comparison with others now available to us. Allowing for errors in recording the contact time, the relative accuracy of the geodetic positions of the various stations and the distances involved, but assuming that the lunar parallax is subsequently determined, it is possible to obtain the geodetic distance with an error of not more than 150 feet.

Military map planners are ever on the lookout for new and better ways and media for portraying terrain data to the soldiers in the field and at the training school. One of the media undergoing intensive research at present is the topographic relief model.

Direct carving of terrain by the process of stereoprojection of aerial photographs using instruments such as the multiplex and stereoplanigraph have been resorted to with limited success. Disadvantages are that terrain cannot be prepared on a curved surface; that horizontal and vertical scale ranges of end products are limited; that contour maps cannot be used for deriving the topography.

Another method being tried out is one utilizing a sharp shadow, point-light source, and a lens of about six-inch aperture, chromatically and spherically corrected for rays parallel to the axis. This has proved more satisfactory than most of the other orthographic projectors previously used.

Greater accuracies have also been introduced in the step modeling process utilizing a German three-dimensional pantograph cutter. Use is made of a zinc plate templet on which contours are etched. A phonograph needle attached to one of the pantograph arms follows the etched contour grooves and results in a product in which operator errors are eliminated.

Two new types of models have been put into production recently. The first one is a model cast in phenolic resin which has been faced with spray coats of zinc and iron thus affording a durable magnetic surface upon which small metal objects such as tanks, planes, etc., can be made to adhere. The second 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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