PARTICIPATION OF I.H.B. IN WORK OF INTERNATIONAL ASSOCIATION OF GEODESY AT Xth MEETING OF INTERNATIONAL UNION OF GEODESY AND GEOPHYSICS HELD IN ROME FROM 14th TO 25th SEPTEMBER 1954

Captain Viglieri, Director of the International Hydrographic Bureau, attended the Xth Meeting of the IUGG held from 14th to 25th September 1954. He participated in the work of the International Association of Geodesy and particularly in the activities of the Triangulations Section, where subjects specifically relating to hydrography were discussed.

The work of the Triangulations Section was carried out under the chairmanship of *Mr. C.A. Whitten*, U.S. Coast and Geodetic Survey. Professor *Kobold*, in the absence of Professor *Marussi*, who was detained by other duties, acted as Secretary.

At the first meeting, general reports on triangulation and control bases, and on radio applications to geodesy were presented, followed by reports of the Presidents of the three groups previously commissioned by the IAG to investigate certain problems of particular interest to the Association.

These reports were discussed during the meetings which followed, at which various papers were also presented.

A complete survey will be published in a forthcoming issue of the « Bulletin Géodésique » of the IAG.

Subjects directly affecting hydrography are discussed in detail below.

General Report on Geodetic Applications of Radio Telegraphy (especially by Radar Methods)

Dr. C.A. *Hart*, of the Nigerian College of Technology, presents his third report on geodetic applications of radio-telegraphy. He describes the advances in this field (which he calls « radio-geodesy ») since his second report was presented at the IUGG Assembly in 1951 at Brussels.

(1) *Computation of long lines*

For a review of methods for computing long lines, he refers to the separate report on the subject presented by Mr. J.E.R. *Ross*.

(2) *Equipment; Instrumental Errors; Observational Techniques*

(a) *Instruments.*

Since 1951, work has been continued in Canada and the United States, where use has been made of *Shoran* or *Hiran* (High Precision Shoran). This is a modification of the Shoran radar bombing equipment, as distinct from the previous adaptations of the standard equipment, for the measurement of long distances with geodetic accuracy. The technique of operation is similar to that described in earlier reports (1), and the modifications to the equipment are for the purpose of eliminating as far as possible instrumental errors in order to improve observational techniques.

Following the U.S. Army Air Force's trilateration of Florida, described in 1951, essentially the same methods were used in the Florida-Puerto Rico Trilateration, but Hiran was utilized. Use was also made of Hiran in making a trilateral connection between Norway and the Shetland Islands by the Army Map Service.

The U.S. Coast and Geodetic Survey uses EPI in certain geodetic as well as hydrographic activities. This equipment is less accurate than Shoran, but it is claimed that it can measure lines 500-800 miles long with a probable error not greater than 100 yards.

A trilateration of a lower order was carried out by direct measurements in the Bering Sea using Shoran and EPI.

In Canada the original Shoran equipment has been replaced by Hiran in so far as ground sets only are concerned.

Decca has also been used for this type of measurement, whether in the Two-Range version in which the master station is carried at sea and the two slave stations are placed on shore about 100 km. apart, or in Short-Base Decca, which is portable and forms two short bases about 10 km. long, each with a master and slave station, and about 100 km. apart. Accuracy to 10 m. in 200 km. is claimed in the former, and to 100 m. in 100 km. in the latter.

In Italy interesting experiments have been in progress since 1951 with prototype equipment. Preliminary results are promising, but no conclusive evidence is yet available. It appears, however, that the apparatus may give good accuracy at shorter ranges than generally employed in Shoran.

In Germany, an equipment on the lines of Bergstrand's geodimeter is being developed, but no significant results have yet been obtained.

The Ordnance Survey of Great Britain have used the Bergstrand equipment to check two bases.

The use of Oboe, adopted in the United Kingdom just after the war, has been abandoned as being too complicated for operational use, although its accuracy was satisfactory.

(b) *Instrumental Errors: Calibration.*

Instrumental errors lead to errors of measurement of the range as time. Their principal errors are due to:

(a) Instability of the time base;

(b) Errors in assessing the time interval;

(c) Errors in assessing the « delay » or time taken for the signals to pass through the electrical circuits at the beacons.

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(1) See « Work of Triangulations Section of the IAG at the IXth General Assembly held in Brussels », by A. Viglieri, *Int. Hydr. Rev.*, Vol. XXVIII, Nov. 1951, pp. 31 et seq.

While the first two can be largely controlled, the greatest uncertainty is found in « beacon » delay, which is affected by variations of signal strength, and partly to overcome this Hiran was developed. In the meantime an empirical correction for signal intensity error was applied with some success. The « gain riding » technique allowing of setting of both airborne and ground stations at the same intensity level by manual control has effectively reduced this error.

Special working methods have been used in Canada. *Ross* mentions that until the recent introduction of the more accurate value for the velocity of propagation, errors arising from the use of the previous erroneous value had been masked by signal intensity error. Having succeeded in reducing the uncertainties in beacon delays by reduction of the effect of variations in signal intensity, it is possible to deal more precisely with the calibration of the beacons, i.e. by assessing variations in delay of retransmission by the beacon, which in Shoran should be about 1 microsecond, or 0.18 mile.

Ross describes the calibration methods resorted to in Canada, where a 10-mile stretch of straight level road was used with markers at intervals of 0.1 mile. A very full description of the maintenance problems of Shoran and ancillary equipment in the field is also given by *Ross*.

(c) *Observational Techniques.*

The technique of crossing base lines is still as described at Brussels in 1951. Meteorological conditions for United States work were determined by weather plane. In the Canadian measurements, the Shoran aircraft is fitted with a psychrometer, and during ascent or descent at about over the mid-point of the base, corrections are recorded according to altitude. Approximate elevations of ground stations are determined by means of aneroids to within ± 20 ft., while those of airborne stations are obtained to within ± 75 ft. The corresponding effect on the accuracy of geodetic distance is significant.

Sixteen separate line-crossing measurements for each line have continued to be carried out, and have moreover successfully been obtained under weather conditions that were formerly considered hardly safe. Measurements of atmospheric factors have been reduced and methods for their reduction simplified, with no decrease in accuracy.

New stations have been selected at a height above the local terrain providing unobstructed ray paths and accessibility of the stations. The plane selects the height at which the signals are best received.

(3) *Velocity of Propagation*

In vacuo, the speed of radio waves is equal to that of light, within the limits of experimental error. The latest determinations by various methods indicate that the value found by *Essen* of $299{,}792 \pm 3$ km/sec. gives greater precision than the values previously used. Observations made under optimum conditions with a microwave interferometer have supplied a preliminary value for the free-space velocity of electro-magnetic waves of $c = 299{,}793 \pm 3$ km./sec., which agrees with the *Essen, Aslakson* and *Bergstrand* values, and appears to confirm that light and electromagnetic waves have the same velocity.

The Shoran operations in Canada immediately after the war were based on *Anderson*'s value of $c = 299.766$ km./sec., with a refractive index of $\mu = 1.0002835$ and a crystal-controlled time-base frequency of 93,109.86

cycles/sec. A revised value of $\mu = 1.000288$, combined with the latest value of c, gave a linear correction of 0.00518 mile per 100 miles. In effect, this represented a change of time-base frequency to 93,114.68 cycles/sec. *Ross* terms this the « frequency » correction to differentiate it from the meteorological correction for velocity.

It is interesting to note that in the recent trilateration with Hiran (Florida-Puerto Rico), length measurements were found to be more accurate when using original values of c rather than the later ones. The discrepancy can probably be explained by the Canadian discovery of compensating errors of velocity and delays, which does not seem to have been used in the Hiran tests.

In the Caribbean Project, trilateration supplied values to within 1 :60 000, i.e. errors of $\varphi = 2$ m. and $\lambda = 2$ m.

Owing to uncertainty of atmospheric conditions near the earth and the effect of the earth's conductivity, radio-geodetic measurements have so far made use of high-frequency transmissions between the aircraft and ground station rather than low-frequency transmission directly between the points to be fixed, although the higher frequencies are limited in range.

Since the refractive index decreases with height, so does the speed of transmission approach that of light, while the effect of the conductivity of the earth decreases. Experiments with Oboe supplied the following results for transmission between the ground and an aircraft: at heights of 10,000, 20,000 and 30,000 feet, the speeds of transmission were respectively 299,713, 299,733 and 299,750 km./sec. On the other hand, the speed of transmission at frequencies of about 100 Kc/sec. (3.000 m.) at a fraction of a wavelength above the earth is reduced by an amount which depends on the earth's conductivity, the overland speed being about 299,350 km./sec.

Measurements carried out between two stations of the English Decca Chain along a particularly non-homogeneous land-path supplied a velocity of $299{,}230 \pm 12$ km./sec. They moreover showed that geological structure has a far greater effect than the ground profile.

The *Essen* empirical formula for determining velocity of propagation under specific meteorological conditions has provided a basis for recent Canadian work; the constants for refractive index, pressure, temperature, and water vapour pressure were determined experimentally.

(4) *Determination of Range*

Various simplified methods of reduction of slant range to geodetic distance have been used, in particular, the assumption that the ray-path between ground and air stations is the arc of a circle.

At first, a radius of 20,000 miles was used for Shoran, but it later became apparent that there were serious shortcomings in such a method where the variations of atmospheric conditions give non-uniform refraction values. In Canada, the circular arc between stations was then considered as being divided into segments of equal height intervals, and each arc-segment converted into a mean sea-level distance by applying a correction depending upon atmospheric conditions. Generally this method is satisfactory if μ varies uniformly with height range.

Another method in use since 1952 consists in dividing the atmosphere between ground and air stations into layers where the lapse rate of μ may be considered to be constant.

Possible errors due to non-horizontal stratification of the atmospheric layers have not yet been seriously considered. The variation of meteorological conditions over a long line at the time of measurement might introduce a significant error from the present assumption of horizontal layers and could probably clear up some of the present unexplained discrepancies.

(5) *Results: Present State of Accuracy of Radar Measurement and Trilateration.*

In the 1951 report, a review was made of results available at that time from work in Canada, Australia, the United States and of the Caribbean Shoran Project.

As a result of the later Florida experiments of the U.S. Army Air Force, it was considered that by holding triangulated arcs for scale corrections and for azimuth control at effective intervals, trilateration equivalent to first order triangulation could be accomplished.

In the Caribbean Project, difficulties over variable signal intensities and uncertainties over velocity of propagation and over meteorological conditions limited the accuracy of the results to about second order accuracy. For lengths of 100 miles or more, the accuracy compared with geodetic distances was generally better than 1 in 20,000 and often as good as 1 in 100,000.

The estimated accuracy (1951) of the Canadian experiment over 1,100 miles of Shoran Trilateration was 1 in 60,000.

Since then, several projects have been carried out, and it will suffice here to consider two only: (a) the Florida-Puerto Rico Hiran Trilateration net; (b) the extension of the Canadian Trilateration over Northern Canada from the Yukon to Baffin Land.

(a) The U.S. Army Air Force carried out a Hiran project to connect Florida-Cuba-Hispaniola-Puerto Rico and a number of smaller islands in the Caribbean. The net was composed of 136 lines having a total length of 21,120 miles and covering an area of 160,000 square miles. The U.S. Coast and Geodetic Survey, in collaboration with the U.S. Army Air Force, undertook the task of adjusting this Hiran trilateration network. The geographical positions of four triangulation stations in Florida upon the North American datum of 1927 were used as a basis. For additional control of the Hiran net, eleven lines between triangulation stations in the islands were available, and for which lengths and azimuths could be computed. Inverses for the lines involved in the Hiran net were computed, and the lengths and azimuths held fixed in two of the four adjustments of the net, all of which were made by the variation of coordinate method. For two adjustments Anderson's value for velocity of propagation of 299,776 km./sec. was used, and for the others the later Bergstrand value of 299,793 km./sec. For each pair, one set of computations made use of the known lengths and azimuths and the other ignored them. The inverses were calculated by machine using a method developed by *B.K. Meade* of the U.S. Coast and Geodetic Survey. The adjustment put the twenty-nine stations on the North American datum of 1927, and makes possible the reduction to the same datum as the United States of all the triangulations of the islands concerned. Of the four sets of computations, the best result was obtained by using the Anderson value for velocity and holding the known azimuths and length conditions. A relative accuracy of part in 57,000 was obtained, and therefore compares very favourably with first order triangulation.

Two interesting points arise. *Firstly*, the best results were obtained from the Anderson value for the speed of propagation, *not* the Bergstrand value. This was probably due to signal intensity errors masking and almost cancelling the error of velocity, as *Ross* recently discovered in Canada. *Secondly*, comparison of resul's with the cases where control lengths and azimuths were not held, shows the tendency of a trilateration net to twist without such control.

An extension of this Hiran net from Puerto Rico southwards through the Lesser Antilles to a connection with triangulation in Trinidad has been started, and the present net may have to be readjusted when this new work is finished.

(b) *Ross* has described the Canadian work since 1951. The number of lines measured between 1949 and 1953 has been 325, the longest being 366.8 miles. 86 Shoran stations have been established with an average length of line of 230 miles and four externally measured lines for azimuth 16, 19, 20 and 48 miles long. These azimuth lines are now considered to be too short for proper distribution of corrections to the longer lines. The practice of including a short azimuth line at regular intervals throughout the trilateration scheme was recently dropped. The increased number of lines required and the limited beneficial effect of the Laplace azimuth made the method uneconomical in a part of the country where the operating season was short. Azimuth control within the net is, however, considered essential.

Long lines are inversed according to the method described by *Ross*, and since the beginning of the Canadian Shoran project, a co-ordinate adjustment system as described in his paper has been used.

As often as possible, check measurements are made over base-lines joining two triangulation stations. Experience has shown that a discrepancy of 25 feet is the maximum to be accepted without thorough investigation into equipment and methods. Secondary checks involve the measurement of lines previously measured to ensure that the accuracy maintained is consistent.

The Canadian Shoran work now extends across almost the whole width of Canada except the Yukon, to which it was also proposed to extend trilateration in the 1954 season. It was also proposed to trilaterate the area south of the Arctic coast with that of the southerly half of Baffin Island, where there will be 18 geodetic stations along the periphery of 4,500 miles for attachment of the net of nearly 100 stations and 380 Shoran Lines. The results of preliminary adjustments confirm the adequacy of the method. By 1953, the work had been adjusted for two major units, the initial arc in Manitoba and Saskatchewan and the work attached to it in the north. The preliminary error in diagonal closure (February 1954), after bringing in the adjustment of the third major unit, gave an error of 1 in 21,000. On the worst basis *Ross* concludes that (a) the closure is satisfactory and the work may be classified as of second order accuracy; (b) better results will be obtained when the final adjustment of all Shoran trilateration is made as a unit; and (c) the first objective of replacing astronomic fixes by positions of greater accuracy has conclusively been achieved by use of Shoran. He feels that the intrinsic overall accuracy using the present methods and equipment is of the order of 1 in 30,000 or better.

Owing to the hard climatic conditions and the short field seasons, many years have already been saved in providing a reasonable geodetic control in the remote areas of Northern Canada.

The Shoran and EPI project in the Bering Sea was mainly a ship project and was of a much lower order of accuracy than the projects described above, it appears, however, to have achieved its purpose of bringing the islands in the Bering Sea in line with the North American datum of 1927. This connection is of strategic importance. The lengths of the lines varied between about 110 and 425 miles and it appears so far that the islands have been fixed with an accuracy of about 1 in 7,000, which may be improved in the final adjustment.

Two Range Decca, as mentioned previously, has been used for fixes at sea by a master station carried aboard ship with respect to two shore slave stations forming a base about 100 km. long. The low-frequency CW transmissions with measurement of phase differences give reliable consistencies up to 150 km. or more with a possible accuracy of 1 in 20,000.

The use of conventional Decca Navigator equipment for trilateration at sea is now generally accepted, since propagation rates over water are readily determinable and predictable.

The Decca Short Base equipment has been designed for mobility and for work of tertiary standard. The two short bases are adjustable to give good intersections of the hyperbolae. The accuracy is said to be of the order of 100 m. in 100 km., and is rather of topographical interest than geodetic.

The check measurements by the Ordnance Survey of Great Britain of the Ridgeway and Caithness base lines by the Bergstrand geodimeter have been described by *Mackenzie*. For the former, just over two miles long, three readings gave discrepancies of 1 in 500,000; 1 in 360,000 and 1 in 420,000, and for Caithness Base, about 4 1/2 miles long, the discrepancies for four readings ranged from 1 in 310,000 to 1 in 480,000. If it were possible always to get accuracies of 1 in 200,000 along a series of triangles, the measurement of precise bases might be obviated.

Information about work now being undertaken in Germany and Italy indicates that it is yet at too early a stage to have any significant influence on the subject.

Research proceeds to improve accuracies and simplify observations. This should be directed to making as many of the observations and settings automatic as will cut out the human source of error. The effective use of radar altimeters could eliminate weather soundings when mid-points of lines are over open water.

Methods of adjustment of trilateration are not discussed in the report, but there is a growing bibliography on the subject.

(6) *Conclusions.*

Dr. *Hart*'s conclusions are as follows. In the first report on this subject at Oslo in 1948, it was stated: « The work done so far shows clearly that the whole approach to geodetic surveys is likely to be modified in the future. » After six years of practical trial, this statement is confirmed in the sense that radio-geodesy is to geodesy as photogrammetry is to topographical surveying, and that it provides a method which can be used to advantage for geodetic work under particular circumstances. It is interesting to recall that a suggestion made in 1946 for the connection of the United Kingdom and Scandinavia by radar ranging has recently been fulfilled by a series of Hiran measurements.

Whether or not results obtained are really geodetic is a matter for debate, but then the geoid itself is still a matter for debate. Work in Canada has shown that control of adequate accuracy and better than astronomical fixes can be extended very quickly over vast areas of harsh climate.

The U.S. connection between Florida and Puerto Rico has shown the value of connecting widely spaced islands with better accuracy than was possible before. Above all, radio-geodetic measurements should be of great value in providing an outside trilaterated framework for connecting continental areas already triangulated so that positions and azimuths may be harmonized over the whole area. Economic applications of radio-geodesy will generally depend upon whether conventional methods can be used more cheaply; whether there is time to use other methods; and whether the radio method can produce the desired accuracy. But a slightly lower accuracy might be accepted if there is no other way of making the measurements. It is interesting to note that during the Carribbean project one of the large islands previously fixed astronomically was found to have a positional error of about half a mile.

There are really two main aspects of the problem:

(*a*) The measurement of long ranges in undeveloped areas or across wide gaps of sea which cannot otherwise be connected than by astronomical means.

The use would be special, and could include connections to provide reduction to common datum. Improvements in instruments, calibration and observational techniques are continually increasing the accuracy of measurements.

(*b*) Precise measures of shorter ranges by means such as the Bergstrand method.

If a field apparatus were available which was simple to use, so that direct measurement of primary triangulation lines could be made consistently to geodetic accuracy, a much wider field would be opened up. It seems that the German and Italian experiments are aimed in this direction.

Finally, Dr. *Hart* suggests that direct range measurement and trilateration arising from radio-geodesy have advanced to the stage where consideration of application of these new methods must be accepted as part of the normal approach to the tasks of geodesy.

Geodetic Interests and Activities of the Army Map Service of the United States of America

(September 1951 to August 1954)

During the second meeting, Colonel *Floyd H. Hough* (U.S.A.) of the Army Map Service submitted his report on the work of an international character undertaken from September 1951 to August 1954 by the Map Service.

Colonel *Hough* opened his statement by enumerating the following items of work carried out:

(a) Completion of the 1,000-kilometer gap in the triangulation of the 30th Meridian Arc in Africa.

(b) Astronomic program along the 30th Meridian Arc from Cairo to Capetown.

(c) Extension of the European Adjustment to the Eastern Mediterranean.

(d) Geodetic connection from Crete to Norh Africa.

(e) Geodetic connection from Norway to Scotland.

(f) Determination of a new figure of the earth.

(g) Intercontinental connections.
(h) Practical application of the Geodimeter.
(i) Field test of Raydist.
(j) Star occultations for long distance measurements.
(k) Progress toward common projection and grid.
(l) Processing of geodetic control.

In connection with Item (a) above, the following resolution was passed by the International Association of Geodesy in Brussels in 1951 :

« *Considering* that the International Association of Geodesy at the occasion of several previous General Assemblies expressed its very deep interest in the completion of the observations of the 30th Arc of Meridian which crosses the whole African Continent, and;

« *Considering* further that the gap existing in this Arc of Meridian covers only a thousand kilometers approximately;

« *Resolves* that under agreement of the interested governments the observations should be carried out as soon as possible and that this chain should be used in the future as a basis for a general adjustment of the geodetic networks of the African Continent.

« *Agrees* to facilitate as far as possible the execution of these observations. »

Following this resolution, the Army Map Service completed the triangulation of the 30th Arc of Meridian from Cairo to Capetown. This concluded a job begun seventy-five years ago by *Sir David Gill*. The part of the arc which had to be completed covered a distance of 1,000 kilometers and extended roughly from 1° north of the equator to 10° North Latitude and lay in three different countries: the Sudan, Uganda and the Belgian Congo. These countries contributed to the work. The observations were carried out between December 1952 and the 27th January, 1954. The office calculations have not yet been completed, but it can now be assumed that an approximation of 1 : 100,000 has been reached. A complete report on the work carried out, the methods and equipment used, etc., will be published soon.

Previous triangulations along this Arc of Meridian included very accurate measurements of angles, bases and numerous latitude stations, but owing perhaps to difficulty in the reception of time signals, almost the entire arc was devoid of longitude stations and consequently of Laplace azimuths. Accordingly, an additional astronomic program of first-order measurements of latitude, longitude and azimuth at intervals of approximately 200 kilometres was undertaken and carried out in August 1954.

The International Association of Geodesy sponsored the extension of the European geodetic net in its southwestern and northern portions. The extension of this net to include the triangulation around the eastern half of the Mediterranean is being carried out and should be completed during the spring of 1955. The adjustment of this large arc had been postponed until the connection between Crete and North Africa was completed.

The following resolution was adopted by the International Association of Geodesy at the Brussels meeting:

« *Considering* that an adjustment of the triangulation around the Eastern Mediterranean will supplement the European network as already adjusted;

« *Considering* that a geodetic connection between Crete and North Africa was recommended at different instances to the interested nations at the occasion of previous General Assemblies and the modern techniques give now the possibility of a very satisfactory connection;

« *Considering* that geodetic operations now underway make it possible to contemplate this adjustment in the very near future, provided that a limited number of triangulation junctions still unobserved, be observed;

« *Resolves* that under agreement between the interested governments, geodetical connection between Crete and Cyrenaica be made as soon as possible;
that the triangulation junction between Turkey and Syria, necessary for the adjustment, be also observed as soon as possible. »

During the spring of 1953, the U.S. Air Force, in cooperation with Greece and Egypt, carried out this geodetic connection between Crete and Cyrenaica using the modern electronic method known as Hiran (High-Precision Shoran). The probable error of the distance from such measurements is of first-order accuracy.

In a similar manner, the Hiran group of the U.S. Air Force, in cooperation with the United Kingdom and Norway, completed during the summer of 1953 a geodetic connection between the modern first-order triangulation of Norway and that of the British Isles.

It has not been possible to meet the wish fo the Union that an adequate international tie be made between the basic triangulation control of Syria and that of Turkey.

As far as the American continent is concerned, basic control now includes a continuous arc of triangulation extending from the United States-Mexican border to South Latitude 45° in Chile. A combination of orthodox triangulation and Hiran control will extend from Florida to Venezuela via the Antilles and should be finished during this calendar year.

Additional control arcs to span the continent will be set up during the next four years for the subsequent establishment of a final South American Datum.

The Army Map Service has been actively engaged for more than a year in the preparatory work for the determination of a new figure of the earth — or at least for a verification of the parameters of the Hayford International Ellipsoid accepted by the International Union of Geodesy and Geophysics in Madrid in 1924 — as there are now far more data available on which to compute the figure than were at the disposal of Hayford over forty years ago.

In addition to the adjusted triangulation of Europe and North America, there are now available long meridional arcs in the Eastern and Western Hemisphere, additional measurements of the deflection of the vertical, and a considerable amount of supplementary gravity data.

It is planned that tentative new parameters will be computed soon from the new long arcs in the Eastern and Western Hemispheres, but that the values will be improved over the next few years as more intercontinental connections and other additional data become available. A Hiran geodetic connection of high-order accuracy between the European and North American Datum could be an accomplished fact in the foreseeable future. The value of this connection alone to the determination of the most reliable figure of the earth can hardly be over-estimated since it will tie together by geodetic measurements the huge triangulation systems of the four major continents of the globe.

The Army Map Service, after several months' experiments, has introduced successfully the use of Bergstrand's geodimeter and obtained results of a very high degree of accuracy. The maximum limit of measurements, using the above instrument, seems to be about 25 kilometres. The geodimeter was used for the measurement of a base in the Antilles for the Inter-American Geodetic Survey. The measurement, for the same organization, of twelve bases in South America is planned for the fall and winter of 1954-1955.

From experience to date, it appears that the geodimeter, using clusters of corner reflectors in place of the plane mirror, is highly suitable for the measurement of base lines in arcs of new triangulation and also valuable in strengthening existing arcs by the subsequent imposition of certain geodimeter-measured lines.

The Army Map Service has also made a full field test with the Raydist equipment. This method differs from Hiran in that it uses longer wave and lower frequency transmission and consequently is not limited by the « line of sight ». This means a lower altitude aircraft and less costly operation in general. The parent company claims first-order accuracy on lines up to 800 kilometres in length. Arrangements have been made for extensive field tests of Raydist for lines from 150 to 800 kilometres long using geodetic lengths already known to an accuracy of 1 : 50,000 to 1 : 100,000. If Raydist is proven to be capable of geodetic accuracy, it will become a valuable and economical instrument in the hands of the geodesist. The tests should be conclusive in this regard.

The Army Map Service has continued with increasing success a programme of observing star occultations for the determination of long geodetic distances. Improvements in instruments and in the technique of observation have enabled the error due to the lack of knowledge of the moon's limb to be reduced. Stars of the 8th and 9th magnitudes have been observed with clear-cut « drops » easily read to 0.01 of a second of time. Except for the ever-present hazard of cloudy skies and the limitation of the working area to tropical latitudes, this method of obtaining long distance up to 1,000 or more miles free from any « deflection of the vertical » has many encouraging prospects for the geodesist.

The following is a third resolution approved by the International Union of Geodesy and Geophysics in Brussels:

« *Considering* that there is an obvious advantage to use in the different countries the same projection system;

« *Considering* that the Tranverse Mercator Projection (Gauss projection) seems to be the most adequate system, as already proposed by the International Association of Geodesy, for a general use up to latitude 80°,

« *Considering* that detailed Tables for this system already exist,

« *Expresses* the wish that the Transverse Mercator Projection in 6° belts in the sheet lines of the 1,000,000 International World Map with a scale factor of 0.9996 should be used in preference to any other system for the computation of geodetic coordinates and for mapping and charting, whenever the interested country finds it adequate and practicable,

There is no question of making an obligation to any country, where geodetic and topographic surveys are well developed, to adopt a new system of projection,

But it is recommended that the proposed projection should be used in preference to any other :

1) in countries recently opened to Geodesy and Topography, for recent and future surveys and for surveys to be undertaken in the future;

2) in the countries already covered by geodetic surveys and topographical maps, whenever a replanning of the topographic and cartographic program is undertaken. »

The wish of the Union with respect to the adoption of the six-degree Tranverse Mercator (Gauss) projection and grid is well along towards realization : this projection has become increasingly accepted in recent years and its use is quite general throughout Europe and Asia; it is official in all French overseas possessions except Madagascar; a resolution of the Commonwealth Survey Officers' Conference in London in 1951 recommended it to all the rest of Africa; the Pan-American Institute of Geography and History, at its session held in Ciudad Trujillo in 1952, passed a resolution urging favourable action for its extension by member countries in the Antilles, Central and South America; lastly, it is official in all of North America.

Thus it will be seen that the Gauss Projection is presently under favourable consideration in 80 % of the land areas of the earth, which is general proof of its superiority over other kinds of projection for world-wide application.

The following resolution pertaining to the European adjustment was adopted by the Triangulations Section in Brussels :

« *Considering* that an homogeneous geodetic network already covers the main part of Europe,

« *Considering* further the subsequent advantages in the International fields of Geodesy, Cartography, Hydrography and Navigation,

« *Expresses* the wish that the results of such adjustments be used by the different Nations as a basis for any work intended to meet international needs. »

As it was recognized in 1947 that certain refinements can be made to advantage in the results of the European Adjustment, it was decided then that at some future time a « second phase » would be accomplished which would improve the first adjustment and would approach the ultimate in scientific achievement.

The results of the first phase have been generally accepted as entirely suitable for all practical purposes.

In 1952, the Army Map Service acquired an electronic digital computer known as the *Univac*. This equipment has greatly simplified the mass calculations of all sorts that the Service has to make. In the adjustment of triangulation, the *Univac* sets up its own observation equations in the variation of coordinate method, prepares and solves the normals, applies the « V » corrections, prints out the final adjusted coordinates, inverses these coordinates for grid azimuths and distances, and converts the plane coordinates to geodetic positions. It is self-checking throughout all operations.

In conclusion, Colonel *Hough* stated that, all things considered, the wishes of the I.U.G.G. in regard to geodetic operations, as expressed in Brussels, have been largely met: the Crete-North Africa connection has been accomplished and the Eastern Mediterranean adjustment is underway; the 30th Arc of the Meridian in Africa is unbroken from Cairo to Capetown; the six-degree Transverse Mercator projection and grid are widely established throughout the world; the European Adjustment has become the basic system of horizontal control in Western Continental Europe and Northwest Africa. These accomplishments in recent years, as was the case of the European adjustment, result from a wholehearted spirit of good will and scientific interest among the free nations. The International Association of Geodesy may well take pride in its active encouragement of this and similar activities which give concrete evidence of a virile international organization and which will in no small way advance the scientific achievements of world geodesy.

Critical Study of the recently adjusted European Net

A Study Group composed of distinguished geodesists had been directed by the International Association of Geodesy to carry out a critical study of the adjustment of the European net made by the Army Map Service of the United States of America, with the cooperation of the U.S. Coast and Geodetic Survey, and completed in 1950. This Group had the task of deciding for what purposes it could be used while keeping in mind the idea expressed by the I.U.G.G. before the work was undertaken, i.e. to prepare a more accurate second phase of the adjustment of the triangulation net in order to satisfy all scientific requirements.

A report on the above subject was presented to the Triangulations Section by the President of the Study Group, Professor *Kneissl*, Head of the German Geodetic Commission, followed by several observations and proposals presented by the Members of the Study Group concerning the second phase of the adjustment. As the report, together with the observations, represents a considerable amount of work, it is not possible to summarize it in a few words, and it will have to be sufficient therefore to mention here only a few points:

I. Discussion of the existing adjusted European Primary Triangulation Net (Réseau Européen 1950: RE 1950);

II. Investigation of the Status of First-Order Triangulation in the European Countries;

III. Drafting of a Plan for a Repeated Adjustment of the European Primary Triangulation Net.

As far as the work already carried out is concerned, the conclusions are as follows: the more or less arbitrary selection of individual figures of the Net (transversal chains and junctions) is unsatisfactory. The adjustment should be based in each case on the existing primary nets; the regional nets should be adjusted separately as such.

The European primary net of 1950 contains deficiencies in several places, and a new revision therefore seems necessary, not only for scientific reasons, but also for some practical purposes. Before proceeding with the new adjustment, however, it will be necessary to study and revise the weak points of the national triangulations; particular attention ought to be given to an examination and revision of available base-line measurements and azimuth observations.

For this first stage of the adjustment, uniform coordination of the first order points was threfore planned. However, subsequent developments and especially economic reasons, called increasingly for a direct coordination of the tasks of scientific geodesy with those of practical land surveying so as to make the results of scientific research applicable to surveying and to draw certain scientific advantages from the extensive practical results of land surveys.

The existing European net is sufficient for the computation of a uniform European Map Net and for all necessary cartographic work on the scale of 1:50.000 and less; it generally satisfies all practical requirements, but owing to fundamental deficiencies in several places, a revision also seems to be desirable for practical purposes.

As a result of checks carried out in several countries between the E.D. and the coordinates of the national nets, Professor *Kneissl* considers that the error in the coordinates might average approximately 4 metres in the middle of the unified net and from 10 to 20 metres on the periphery.

The second phase of computation should be carried out with all possible precautions and this will take some time. The necessary time can be estimated at about 10 years. Each interested nation should make its contribution while examining with a critical spirit its own nets, in some of which deficiencies exist, particularly base deficiencies.

This work will imply a considerable financial outlay but would be facilitated with the help of the Coast and Geodetic Survey, particularly because of the experience acquired by the Survey in the first stage of the adjustment.

Several technical suggestions for the carrying out of this second phase have been submitted by the Members of the Study Group.

During the discussion on the subject, Colonel *Schive*, Head of the Norwegian Army Map Office, presented to the meeting a memorandum which aimed at clearing up the following points, i.e.:

(*a*) Whether the results of a new adjustment of the European net could be expected in the near future, and

(*b*) The extent to which it could be assumed that the new data would differ from the positions calculated in the recent adjustment,

in order to decide whether it was desirable to introduce the adjusted European net data at once into the cartography of Norway.

The President of the Triangulations Section, Mr. *Whitten*, then set up a small working party presided by Professor *Kneissl* to investigate the problem and to submit a revised plan to the Section. The conclusions arrived at by this latter party were approved by the Study Group in full.

It was stated that a more accurate adjustment for scientific purposes was under discussion, and that it might take ten years to complete. It was also considered that the data of the first phase of adjusment provided an approximate value of such an order that later geodetic operations would not materially affect internal accuracy, and that the first-phase adjustment is currently suitable for nautical, hydrographic and cartographic purposes.

Consequently, Mr. *Whitten* presented to the fifth meeting of the Triangulations Section a draft resolution which was approved by the I.A.G. in the following form:

« *Considering* the conditions under which the general adjustment of the European Triangulation Net has been performed during the preceding period,

« *Expresses the Hope* that an agreement could intervene between the interested countries in order that such homogeneous data obtained therefrom be used in the compilation of nautical charts and in the publication of data useful for navigation. »

The other reports put before the Section were the following:

— « General report on triangulations and bases by Chief Engineer *Salvioni* (on behalf of Professor *Marussi*) », indicating that geodetic operations are generally carried out by the various countries with regularity and method and are progressing according to I.U.G.G. recommendations.

— « Report by the President of Study Group No. 1 (Brigadier *Hotine*) on the calculation and the adjustment of large triangulations ».

— « Report by the President of Study Group No. 2 (Mr. *Ross*) on the computation of Shoran nets ».

The latter report consists of three parts: in the first, entitled « Long Lines », the author studies the various formulae and methods which may be used for the computation of long lines, which can now be measured by radio. Some of these methods had been left aside owing to the difficulty of preparing tables for computation purposes, but now they are being considered again, since electronic computers greatly facilitate calculation.

The second part consists of a comprehensive bibliography including:

(*a*) articles relating to electronic length measurement and adjustments, and
(*b*) long line computation.

Finally, the third part refers to observation equations and other formulae which are considered most applicable in the adjustment of Shoran trilateration.

In addition, Mr. *Ross* presented a full report on trilateration in Canada from 1941 to 1953. Several points dealt with in this report have been included in the report by *Hart* which has already been summarized. It appears from this report that plans for the year 1954 provided for the closure of the Yukon Territory area thus supplying another connection with the geodetic control along the Alaska-Yukon boundary. A detailed description of Shoran electronics and the instruments used for the operations in Canada was published in the « Empire Survey Review » in April and July 1954. In both these branches, no modifications were introduced except as regards the ground sets, which were replaced by Hiran.

Other papers on technical subjects and concerning highly useful new instruments in geodetic work were communicated to the Section. The most important of the latter are the followings:

— *A New Method of Collimation with a Theodolite,* publication of the Netherlands Geodetic Commission, by P. RICHARDUS.

This paper describes a new method of collimating developed during the years 1950-1951 in the Geodetic Institute of the Technological University at Delft. This method permits a high accuracy of pointing to be achieved over short distances by the « precision alignment method » and even under unfavourable circumstances. The method was also applied on longer distances up to 46 km.

The optical collimation consists in placing before the object lens of the theodolite a circular zone plate with concentric slits producing diffraction images according to the principle of the classic experiment of Young; the center of diaphragm and the center of index are brought under alignment with the intersection point of the cross-wires. For distances from 250 m. and up to 10 km., simple signal lamps are used and for distances from 10 km. to 45 km. more powerful automotive spot lamps of a diameter of 11.5 cm. are used.

During experiments performed under all kinds of weather with Wild theodolites (T4 enlargement 65 or T3 enlargement 40), the standard errors in pointing are of the order of 0″,2.

— A Paper by Drs. T.J. KUKKAMAKI and T. HONKASALO of the Finnish Geodetic Institute concerns the application of a light-interference Väisälä comparator to the measurement of the standard base line of the Military Geographic Institute in Buenos Aires, in June, 1953.

Such operation was carried out on the basis of a proposal formulated by Dr. *W.A. Heiskanen* and agreed to at the Brussels Assembly (1951) of the International Association of Geodesy, which suggested that the standard base line be measured in different countries with a light-interference apparatus, by the interested Geodetic Services, to compare the results obtained by this process with those obtained by wires or tapes.

The base established by the Argentine Military Geographic Institute is 960 m. long and consists of five massive concrete underground marks on each 240 m. and the smaller subsoil concrete posts on each 24 m. The South-Western half of the base line was selected to be measured by Väisälä comparator and the necessary concrete pillars were erected and the wooden shelters built 3 m. from the base line to the SE at distances 0, 1, 6, 30, 60, 120, 240, and 480 m. from the center point of the base line to its SE-end.

For the determination of the refraction correction, thermometers were placed at the distances 1/2, 2.5, 12, 24, 48, 72, 96, 120, 144, 168, 192, 216, 264, 312, 360, 408, and 456 m., linear changes of temperature being assumed from one thermometer to the next. In addition, inside and outside temperature difference were taken into consideration.

For interference observations two quartz meters, No. VIII and No. XI, were used. Their lengths are as follows:

$$\text{No. VIII} = 1\text{ m.} + 150.25\mu + (t - 20^\circ)\ 0.430\mu + (t - 20^\circ)^2\ 0.00159\mu - (B - 760)\ 0.00347\mu$$

$$\text{No. XI} = 1\text{ m.} + 136.34\mu + (t - 20^\circ)\ 0.434\mu + (t - 20^\circ)^2\ 0.00159\mu - (B - 760)\ 0.00477\mu$$

For the projecting of the indexes in the Väisälä comparator to the base line defined by the underground marks, a Wild Theodolite T3 and plumbing bar were used, erected vertically by aid of a level of high sensitivity. The accuracy of one projecting measurement series was ±27 μ.

The results of interference measurements are as follows for the shorter distances :

Mirror Interval	Distance
from 0 to 6 m.	6000.789 mm. ± 2.0 μ
from 0 to 30 m.	30004.163 mm. ± 5.6 μ
from 0 to 60 m.	60008.439 mm. ±29.4 μ
from 0 to 120 m.	120016.727 mm. ± 7.5 μ

The results of interference measurements for 240 and 480 m. are as follows ·

Distance 0 — 240 m.	Distance 0 — 480 m.
240 m.	480 m.
average — 13429 μ ±15.9 μ	average — 162.7 μ ±7.6 μ

These results include a certain number of reductions as given in the following table :

Length of the standard base line

		240 m.	480 m.
	Result of interference measurement	— 13.429 mm.	— 16.217 mm.
1.	Half of 0 m. - mirror thickness	+ 10.048 mm.	+ 10.048 mm.
	Half of terminal mirror thickness	+ 10.008 mm.	+ 10.018 mm.
2.	Correction due to the mirror coatings ..	— 0.017 mm.	— 0.034 mm.
3.	Air Pressure correction	+ 0.003 mm.	+ 0.010 mm.
4.	Inclination correction	— 0.990 mm.	— 1.980 mm
5.	Correction due to the deviation from the parallel of the base line	— 0.001 mm.	— 0.002 mm.
6.	Correction due to the slant of the mirror caused by refraction	+ 0.004 mm.	+ 0.009 mm.
7.	Correction to the elevation of the invar wire measurement	— 0.032 mm.	— 0.070 mm.
		+ 5.594 mm.	+ 1.782 mm.

The measurement with the Väisälä comparator gives for the length of the South-Western half and of the second quarter from the South-Western end of the Standard Base Line the following results:

480001.78±0.05 mm.
and 240005.59±0.04 mm.

Accuracy. — The total error of length, taking into account the effects of different sources of error: error of distance, error of comparison, error of projecting, error caused by movement of comparator pillars, has been estimated as follows:

error of length of 480 m. is ±54 μ
error of length of 240 m. is ±39 μ

— The paper by Professor Erwin Gigas of the Institute of Applied Geodesy, Frankfurt-on-Main and entitled : *Die Entwicklung des Verfahrens zur Messung von Distanzen mittels Modulation hochfrequenter Lichtwellen* (Development of process for distance measurement by modulation of high-frequency light-waves) outlines the earliest attempts to measure distances or the velocity of light by means of modulated light waves, and describes the various devices used for the purpose. The article discusses the improvements to which Bergstrand's instrument (geodimeter) was subjected in order that it might be practicable for measuring polygons with sides up to 4 km. in length, thus enabling the substitution of series of accurate polygons in third-order triangulation. Developments at the Institute in the construction of the EMc instrument are also described, in which the size has been reduced to that of a theodolite and which can be placed on a standard tripod.

In the Bergstrand equipment, the light is modulated in a Kerr cell, and a high-frequency signal of 2,000 volts is superposed on a low-frequency signal of 5,000 volts. Owing to the high voltage of the signals, the power consumption is fairly high; the transmitter, which contains about 50 tubes, is complex; and the total equipment is both bulky (around 100 kgs) and expensive.

In the new instrument, prior knowledge of approximate distance values is no longer necessary in order to compute the number of whole multiples of the wave length. The present model is equipped with two crystals of different frequency enabling an additional value of the distance to be determined independently, as well as whole multiples of the wavelengths by combining the two values.

Specifications of the Type EDM electro-optical instrument as built by Askania-Werke A.G., Berlin-Friedenau, are supplied below :

Utilization: High precision measurement of geodetic distances for triangulation purposes.

Scope: 200 to 2,000 metres.

Description: The EDM consists of the measuring device proper, the electrical power and plane mirror at the target. The measuring device and mirror may be provided with appropriate pivot-journals for use on standard tripods of theodolites (centering for the three-tripod system of traverse measurement).

Principle: The measuring device emits high-frequency modulated light waves, receiving their reflection from the plane mirror, following intervening modulation. The distance is expressed in wavelengths of the modulated light wave.

Electrical characteristics: 250 VA approx. (6-volt battery).

Dimensions and weight:

Measuring device:	$35 \times 15 \times 25$ cm.	11 kg.
Plane mirror:	$15 \times 15 \times 25$ cm.	5 kg.
Power supply unit:	$35 \times 20 \times 20$ cm.	11 kg.

— A publication by Professor GIGAS entitled: *Die Frage der Notwendigkeit der Wiederholung von Basismessungen im Europäischen Dreiecknetz, Neue Gedanken zur Beschleunigung der Triangulation* 1.0 (The need for repeating base measurements in the European Net: new processes for speeding up first-order triangulation) was also distributed. Among these Professor Gigas describes a theodolite which records photographically and a device known as the electric eye (das elektrische Auge).

— A report submitted by Dr. ARNE BJERHAMMAR, Stockholm, describes a new method of electro-optical distance measuring. The Royal Institute of Technology at Stockholm is developing a new process whereby the light is modulated directly by means of an oscillating crystal in the one and only stage of a transmitter. The modulating effect is obtained from ultrasonic waves in the crystal. The transmitter hitherto used contains a single tube, and the light-modulating power is of the same order as in a Kerr cell. The power consumption is from 10 to 20 times smaller than in a Kerr cell, and the weight of the transmitter is only about 200 grams. The receiver consists of a photocell unit and a phase indicator. Phase indication occurs at a considerably longer wavelength than the original wavelength.

Accuracy of the new method seems to be of the same order as in the earlier Kerr cell method. The weight and manufacturing cost are low, and the new system holds great promise as a new distance measuring technique.

— Improvements in electronic and manual computers of functions were also described and photographs were shown of some of them. They had been constructed for the calculation of trigonometric functions and square roots; and provide correct interpolations up to 5 or 6 decimals.

The resolutions adopted by the Triangulations Section were the following:

The International Association of Geodesy,

« *Considering* the conditions under which the general adjustment of the European Triangulation Net has been performed during the preceding period,

« *Expresses the hope* that an agreement could intervene between the interested countries in order that such homogeneous data obtained therefrom be used in the compilation of nautical charts and in the publication of data useful for navigation ».

The International Union of Geodesy and Geophysics,

« *Considering* that the countries of Europe which have participated in the first phase of the European triangulation adjustment are now determining the best procedures for continuing that work into a second and more scientific phase,

« *Resolves* that these member-countries adopt the following program in so far as as possible:

1) Complete the scientific analysis of the results of the 1st Phase.

2) Improve and complete the observations along the borders between the various national nets.

3) Establish a standard base-line in each country using the Väisälä method (or similar apparatus) for assuring a uniform scale in all networks and for calibrating invar tapes and geodimeters.

4) Increase the density of Laplace Azimuth and base-lines, either invar tape or geodimeter by a uniform European plan so that an overall accuracy of 1 part in 100,000 may be expected; and

5) Consider supplementing national nets or international connections with high precision Shoran in an effort to obtain greater accuracy in the final adjustment ».

The International Association of Geodesy,

« *Considering* that it is not feasible for each country to obtain the special equipment required for making precise geodetic length measurements,

« *Resolves* that the Central Bureau initiate plans for the organization of an international base measurement and geodimeter party, when it is fully determined that the latter method is satisfactory, with the equipment to be supplied by some of the larger countries and the cost of the personnel to be contribued by the countries actually engaged in the project ».

Other resolutions approved by the plenary session of the International Union of Geodesy and Geophysics and of possible interest to Hydrographic Offices are the following:

The Internationl Union of Geodesy and Geophysics,

« *Considering* how important it is to make gravity survey in the vast shallow water areas of the Oceans and knowing that the under-water gravimeters offer a fast and accurate method of making such surveys,

« *Recommends* that the countries which have large shallow water areas should carry out under-water gravimeter measurements on as large a scale as possible. »

The International Union of Geodesy and Geophysics,

« *Considering* that an adequate knowledge of depths of Oceans and of values of gravity throughout the entire globe are necessary in order to determine the exact shape of the earth and of the external gravity field,

« *Considering* that both the exact shape of the earth and the external gravity field are of great and increasing importance in modern times,

« *Considering* that in exterior regions, especially the Pacific, the Indian Ocean, the South Atlantic and the Polar regions, data for either or both depths and gravity are non-existent or inadequate,

« *Considering* that great efforts will be needed to provide this data and that these efforts are urgently necessary,

« *Resolves* to call upon National Committees of all maritime countries adhering to the Union to bring to the notice of their governments the high importance of extension depth measurements by echo-sounding in surface ship and of gravity observations in submarines, and to request that results should be compiled and published periodically as soon as available ».

A. V.