UNITED NATIONS
ECONOMIC
AND
SOCIAL COUNCIL

58545

Distr.
LIMITED

E/CN.14/CART/156
22 July 1966

ENGLISH
Original: FRENCH

ECONOMIC COMMISSION FOR AFRICA
Second United Nations Regional
Cartographic Conference for Africa
Tunis (Tunisia), 12-24 September 1966
Provisional agenda item 12(a)

GEODETIC FLARE TRIANGULATION

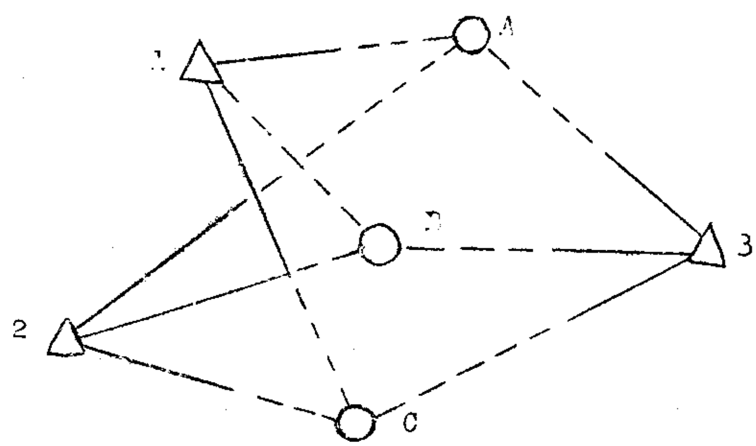
Technical paper submitted by the French Government

M66-965

FLARE TRIANGULATION[1/]

The principle governing the geodetic method of simultaneous observation of parachute flare is not new. Frequently referred to in English as "Flare triangulation", this method had previously been used in certain long distance geodetic connexions, but the accuracy of the results was comparatively poor owing to difficulties in obtaining simultaneity.

The studies and experiments conducted at the National Geographical Institute in the last two years have resulted in the development of a simple operation procedure as well as a simple equipment which gave very satisfactory results in terms of precision, and the accuracy compares favourably with other methods that are more expensive and more complicated.



Principle

Given two points (1) and (2) connected geodetically, one propose to determine the co-ordinates of a third point (3) not visible from the first two. Flares are dropped from an aircraft, and serve as light signals to be observed simultaneously from the three positions (1), (2), and (3). If A, B, and C are three flare positions in the zone of

1/ By the National Geographical Institute.

release, the points A, B, and C are calculated from (1) and (2) by intersection, and (3) is calculated from A, B, and C by resection. Once the position of (3) is known, it can be used to determine the position of another point which we shall denote as (4), and so on.

At each point the astronomical co-ordinates are determined, giving the deviation of the vertical, as well as a Laplace azimuth.

Technique of measurement

Observations are made at night with Wild T 3 theodolites, in exactly the same way as with usual measurements of first order.

A 10^6 candle flare is dropped from an aircraft flying at an altitude of approximately 8 kilometres. In order to slow down the speed of fall, the flare is fitted with a parachute. The observation team using a reticule, follow the flare as it moves slowly, and take simultaneous readings as they listen to the "pips" of a time signal given by a quartz clock.

In practice, the observation "pips" are sent out at intervals of 10 seconds, and there is a cautionary "pip" warning the observer team every two seconds before. The emission schedule is as follows:

	Warning	Observation	Warning	Observation	Warning	Observation
t.	8 sec.	10 sec.	18 sec.	20 sec.	28 sec.	30 sec.

Generally speaking, it is possible to take 15 to 20 readings on the same flare (the flare lasts approximately 4 minutes).

The precision of the synchronization of clocks at observation stations is approximately 1/100 of a second, verified with the help of international time signals (T.U.). The equipment which consists of a radio receiver at each station, a quartz clock and a selector is simple, accurate, resistant and not too cumbersone. It was thought out and made at the Radio Laboratory of the National Geographical Institute.

Every night the aircraft flies over the three release zones A, B and C dropping 2 to 3 flares in each zone, in accordance with a pre-arranged timetable. The pilot and the observer team are in constant touch by radio. To achieve the required degree of accuracy, there must be at least two flights on different nights.

The astronomical co-ordinates are observed on the same nights, by the method of equal heights at the zenith distance of 30°.

The Laplace azimuth is observed by circumpolar star method, generally on α U. Min. at the maximum degree of elongation.

Computation and adjustment

For small networks of 3 to 4 points, the computation is easily done by the graphical method of geometrical loci, which consists of drawing on a special sheet, a large scale graph of the positions obtained of the various observations.1/ In the case of large networks, adjustment is achieved by the method of least squares.

It is worth noting that if the horizontal angular displacement of the falling flare is less than 0.5 of a degree, mean value of simultaneous readings at each station may be regarded as defining the position observed by theodolite. This makes it possible to reduce the number of auxiliary points of A, B and C to 5 or 6 adequate for a solution.

It is interesting to note that observation of the azimuth at each station provides a redundant condition for fixing the position of the unknown point: it is clear that the position of point (3) can be calculated only by resection from points A, B, and C. The sighting 3 - A, 3 - B, 3 - C is an additional condition for determining the point.

It is to be noted that the determination of the astronomical co-ordinates at each station gives the deviation of the vertical as it exists there, and makes it possible to take account of the Laplace relationship in the orientation of the station.

1/ Method used in France to calculate isolated points of triangulation. In such a case, same results can be obtained by the method of least squares.

Results

An initial experiment was carried out in September 1964 to test the accuracy of the readings.

A team of three observers, using the equipment mentioned above worked with three Wild T3 theodolites which were synchronized as perfectly as possible. After reduction to the same origin, the mean value was taken and the difference between each individual reading and the mean value were studied.

The difference noted was ± 5 to ± 6 sexagesimal seconds. These measurements were taken on 9 flares dropped in three nights with approximately 15 readings on each flare.

Later in the summer of 1965 the National Geographical Institute carried out a similar operation in an archipelago where the islands are 200 kilometres away from each other. The computation now being completed shows that the mean error of position for any of the points A, B and C (with 15 readings per flare) is approximately ± 1m, and as a result, the mean error for point (3) is ± 1.5 m.

In this second experiment, two theodolites were at each station sighting simultaneously on each flare; the observations of these two theodolites which are oriented on a ground reference were reduced to a common point and checked against each order (see Annex).

Large triangulation networks

Flare triangulation seems to be very well adapted to the establishment of vast networks containing long triangulation sides and, therefore, a reduced number of points (density: 1 point per 20 to 50,000 square kms.) It is of course necessary to provide a fundamental point (or to establish one)from the existing oriented bases of 200, 250 kms. between two terminals. Such bases may be the classical triangulation nets (or traverses nets) on a known accurate scale. The first order should be made up of triangles which are observed in accordance with the standards of the first order accuracy: in each triangle one side at least should be measured by an accurate electro-magnetic method and at its each end a Laplace azimuth observed (accuracy: 0".5).

Conclusion

The method outlined will thus make it possible to establish a geodetic network of first order with excellent accuracy (better than 1:100,000) in areas in which travelling is difficult or impossible, and to connect points of long distance and spreading over wide stretches. It is comparatively simple to put into practice and only requires equipment which is strong, not too cumbersome, easy to handle and, the most important of all, cheap.

On the other hand, it entails making observations at night and, above all, calls for favourable weather conditions, namely, a clear sky over the whole operational zone, since light signals should in principle be simultaneously observable from all stations.

Date : 4 Juin 1965

Signaux horaires : WWV : 5,0 MHz

Secrétaire :

Visibilité :

Obs^rs ① : M^r MEYER T3

Références : SEARA

② : M^r RENAULT T3

LAGO do PILAR

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radio : 930	375 G	1535 "	375 G	2043 "		
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20		3996		4683	4003	+7
30		3743		4432	3752	+9
40		3613		4308	3628	+15
50		3599		4276	3596	−3
1 H 31 m 00 s		3520		4206	3526	+6
10		3441		4118	3438	−3
20		3461		4149	3469	+8
30		3368		4045	3365	−3
40		3294		3996	3316	+22
50		3303		3980	3300	−3
1 H 32 m 00 s		3208		3888	3208	0
10		3139		3819	3139	0
20		3073		3756	3076	+3
30		3079		3766	3086	+7
40		3000		3690	3010	+10
50		3041		3723	3043	+2
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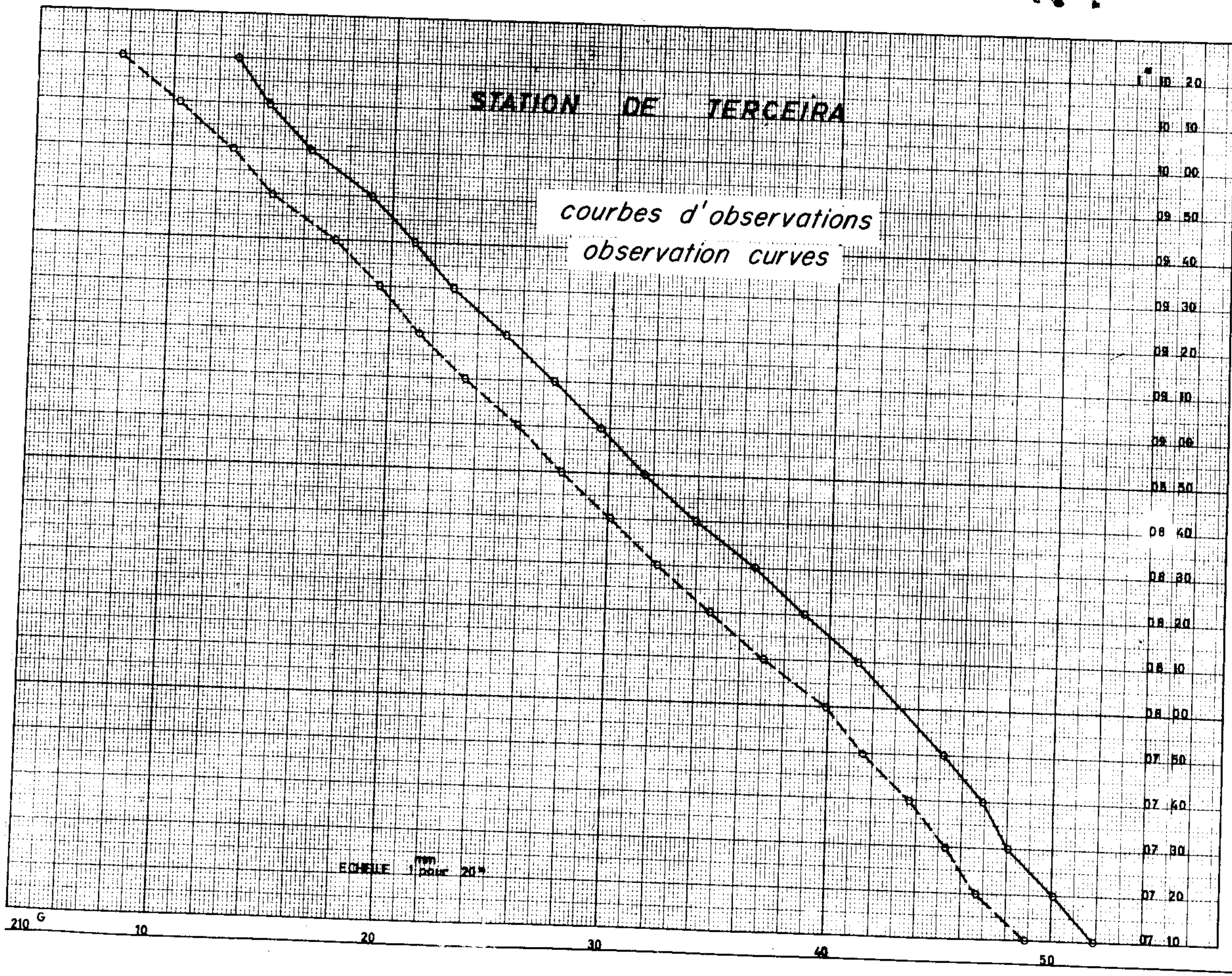
STATION DE TERCEIRA
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observation curves
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