TRIANGULATION CONNEXION OF NORWAY AND DENMARK

by Lieut.-Col. W. E. BROWNE, M.B.E., R.E.
(*Chief, Survey Sub-Section, G-3 Division, SHAEF*).

PARTS

I.—INTRODUCTION.

1.—At the writer's instigation, a survey project was launched by SHAEF of linking the first order triangulation nets of Denmark and Norway. The expanding use of Radar navigational aids necessitated the procurement and use of geodetic data as a basis, and an investigation of the available data in Denmark and Norway revealed the fact that those two countries were not reliably connected one to the other; so that, it might be possible that a fixation of position from Radar stations located in Denmark would perhaps not agree with a position fixed from similar Norwegian stations. As the distance across the Skagerrak is about 90 miles and the two countries are not intervisible, it was decided to utilize a new survey method devised by the writer for carrying out the necessary surveys.

2.—The Danish and Norwegian authorities gave their consent and very active support to the scheme in the form of supplying some observing parties and instruments. Further observing parties were furnished by Colonel Milwit, Chief of the Intelligence Division, Office of the Chief Engineer, U.S. Army, European Theatre of Operations. Signals personnel and equipment were furnished by the Chief Signals Officier, H.Q. 21 Army Group and the necessary aircraft and personnel were provided by 2nd Tactical Air Force (R.A.F.), also of 21 Army Group. To all of the above, acknowledgment is made of their great contributions to the scheme, without which the operation would have been impossible. Also, to all concerned who took part in the survey operations in the field, acknowledgment is made of their splendid work done and cooperative spirit shown at all times.

3.—The *old* Norwegian and Danish nets were, after a fashion, previously joined through the old 1815-17 Swedish first order chain along the west coast of Sweden. The identity of common points was doubtful; also, the accuracy of the chain somewhat questionable. The *modern* first order triangulation nets of Denmark and Sweden are firmly linked; but those of Norway and Sweden appear to be joined at one point only, so that no net extension is possible into Norway from the other European first order chains. It is added that the identity of this common point is also open to doubt.

4.—The connexion of the new Norwegian and Danish nets planned by the writer was by observing simultaneously from both sides of the Skagerrak to parachute flares dropped by aircraft at night, the times of observation being given by radio time signals. Three triangulation stations on each side of the Skagerrak were occupied and flares dropped at three stations, A, B, C, in the sea.

5.—This method is an original one of the writer and as far as is known has not been employed before anywhere(*). Actually the writer planned a similar connexion between Normandy and the opposite English coast in July, 1944, shortly after the invasion. But lack of aircraft and operational difficulties ruled out the execution of the method and a substitute was employed, that of towing balloons by PL's in the Channel (See Appendix A). Again, this latter method, after one trial, was abandoned owing to the lack of signal facilities.

6.—A total of sixty-four arcs (positions) was planned originally as the desirable number of observations required. This number was based on the assumption that only two shots on each flare could be observed. Very early in the observations it was found that four shots could be observed with ease and so in consideration of this as well as the fact that two instruments at each station would be set up, the number of arcs to be observed was reduced to thirty-two. Actually, it was not possible in all cases to observe four shots on every flare owing to signal and reception failures, extinction of flares before the normal time of burnt-out, cloud, and so on. Finally, owing to the breaking up of the air squadron, a total of thirty arcs only were observed. These do not represent complete arcs, as some stations missed observations of some flares altogether, whilst some would perhaps have got only one or two shots on a flare.

7.—Apparently there is only one time of the year in the Skagerrak, and in Denmark generally for that matter, that the weather is really favourable for first order observing, and that is in the month of September. Our observations started on 15th July, 1945 and the last night of observations was 3rd August, 1945. During that period we had about 30% really good observing nights. In general, weather conditions in Norway were much better than in Denmark; at the end of July and the beginning of August we experienced nights when the visibility in Norway was as perfect as could be expected, but in Denmark a sea mist would float in, blotting out everything up to a few hundred feet distant from the observing station.

II.—COORDINATION AND PLANNING

8.—The coordination and planning was a difficult and lengthy task, mostly because of the enormous distance separating all the people concerned. The task of obtaining the cooperation of the Norwegians and Danes, as well as their consent to carry out the project, was not an easy one.

9.—Two technical meetings were held in Copenhagen at the Geodetic Institute, to work out the details of the job and to decide upon the equipment and personnel required. Present at these meetings were representatives (**) of the Danish Geodetic Institute (Prof. Norlund, Director); the Norwegian Geodetic Institute (Major Schive, Director); H.Q. Allied Force, Norway (Lt.-Col. Dennis); Royals Signals (Major Darwell-Smith); Royal Air Force, 2nd TAF, (Group Capt. Bowen); Air Liaison Section, 2nd TAF (Capt. Stopford); and, SHAEF (Lt.-Col. W. E. Browne) under whose control the work was being done.

10.—The final composition of the parties was as follows :—

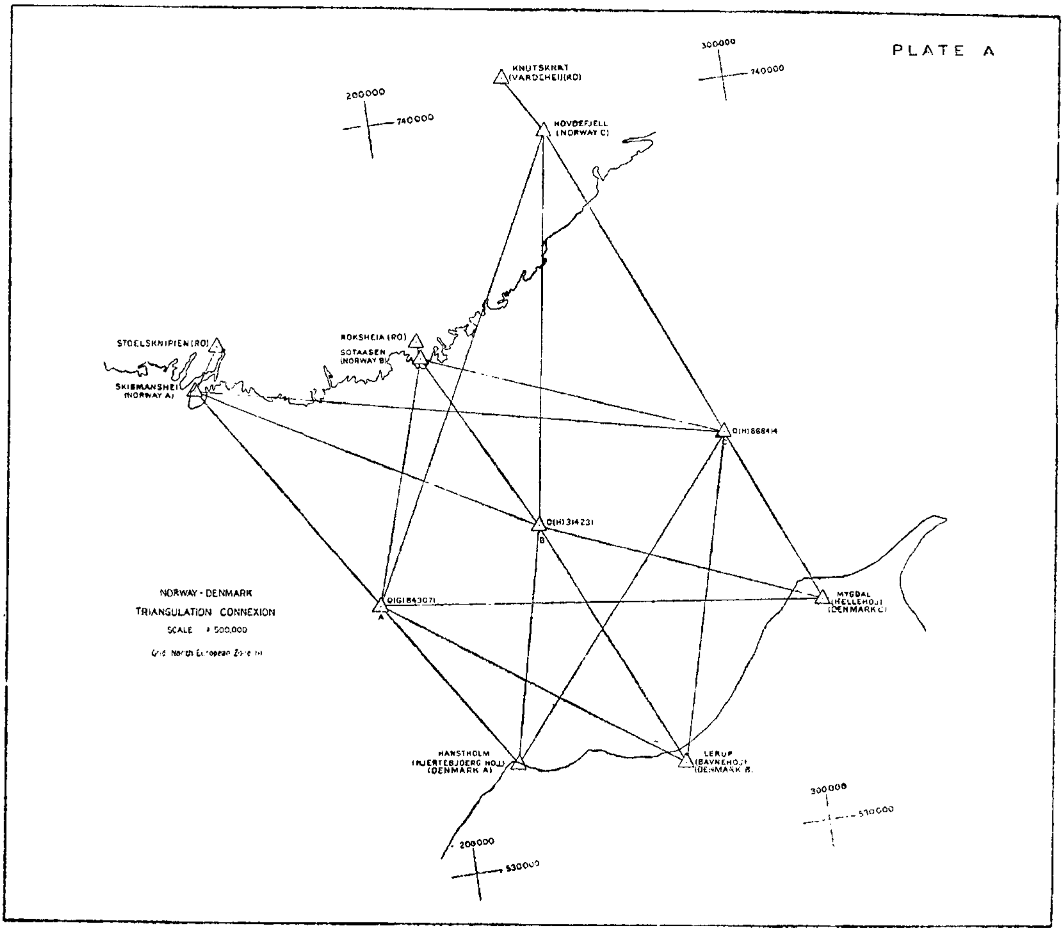
(a) IN NORWAY.

1° All three stations to be manned by U.S. Army Observers drawn from 660 Engrs. U.S. Army. Also, two of the same stations to be manned by observers from the Norwegian Geodetic Institute. Thus, the Americans had one observing party at each of two stations, and two observing parties at one station; the Norwegians had one observing party at each of two stations. The Officer in charge of the Norwegian Survey party was Major Grinacke of the Norwegian Geodetic Institute and the Officer in charge of the American Survey party was Lieut. Shirley, of 660 Engrs. U.S. Army.

2° All three stations to be manned by Royal Signals drawn from Phantom (GHQ Liaison Regt.) under the direction of Capt. The Earl of Rosslyn.

(*) The Germans have designed a Bamberg theodolite with photographic registration and radio time signal recording gear for observations on flares dropped from aircraft. The Germans intended to join the island of Bornholm to the mainland of Germany by a method similar to that of the writer, but it never materialized.

(**) The principals only are listed



(b) IN DENMARK.

1° All three stations to be manned by observers from the Danish Geodetic Institute. Three observing parties for each station were provided, working under the direction of Captain Chantelou, Chief Geodesist at the Institute.

2° All three stations to be manned by Royal Signals drawn from Phantom (GHQ Liaison Regt.), under the direction of Capt. Lucas.

3° 2nd TAF, Royal Air Force, to provide nine Wellington aircraft with crews and ground staff, also personnel for flying control and to man a radio-transmitter with Royal Signals for direct communication with aircraft whilst in flight. This detachment was drawn from 69 Squadron R.A.F., with 2nd TAF and was a night air reconnaissance squadron who were well experienced in night flying and precision navigation and bombing, all asserts that stood them in good stead for the work performed.

11.—Visits were made by the writer to Oslo to make arrangement for the reception of the American party and for their supply with tents, transport, and rations, who were to fly up to Oslo from Paris. Also, a flying visit was made to Aalborg airfield to determine its suitability as a field for operations for the Survey. Adaquate accomodation was found there moving some German refugees, but there were no R.A.F. personnel on the field other than one R.A.F. Disarmament Section who where taking over equipment from the German Lufwaffe still present at the station.

12.—The writer was in sole control of the entire survey operations, with Headquarters at Aalborg, but controlling all observations from the Central Danish Station at Lerup.

13.—The R.A.F. brought along Capt. Stopford, their Air Liaison Officer, who proved invaluable and is a definite asset when coordination with another arm of the Service is involved.

14.—The writer's personal staff consisted of one Computer, Sgt. Cheverton. who was the Chief Computer in the Map and Survey Section, G-3 Division, Shaef. The writer had no transport, but a Chevrolet Sedan was provided for the duration of the survey by the Chief of the Danish Resistance Group in Aalborg.

III.—OBSERVATIONS.

15.—All observations were carried out following the methods of first order practice and using the direction method, as the target observed was a moving one of course.

16.—The observations were carried out in such a way that circle positions were selected for each night's work so that graduation errors would ultimately be eliminated. For example, the Danes and Norwegians carried out the following procedure of circle setting for each successive arc :—

Setting No. or Arc.	Graduation Reading.
	0
1	0
2	90
3	30
4	60
5	120
6	150
7	10
8	40
9	70
10	100
11	130
12	160
13	20
14	50
15	80
16	110
17	140
18	170
19	5
20	95
21	35
22	65
23	125
24	155

and so on. The Americans followed an almost similar procedure.

17.—The Norwegians used the large old-fashioned Hildebrand geodetic theodolites for their observations. The Danes used more modern Bamberg theodolites and the Americans used the Wild T3 geodetic theodolites. Major Grinacke and Capt. Chantelou decided to use the old instruments in preference to the more modern Wilds at an experiment carried out at Kastrup airfield before operations began in Jutland.

18.—As time was so short both Danes and Norwegians had four men at each instrument, one to observe, two to read—one at each micrometer—and one to record the observations. With the Wild T3 this was not necessary and an observer and recorder was required for each instrument.

19.—In Norway two instruments at each station were set up, one or sometimes both being satellite stations. In Denmark three instruments at each station was set up; but in all cases the third instrument was a Wild or Zeiss instrument which was used for piloting purposes only or for plotting the position of the aircraft during flight (See Part V para. 49).

20.—The recorder at each instrument also recorded the time (Double British Summer Time being used throughout) of each pointing on a flare. This was done for identification of the individual observations on the flares.

21.—The observing procedure for one complete arc or circle position was as follows :—

a) Set selected circle reading on RO (i.e. zero mark) (RO = Referring Object) ;
b) Just before observations observe on RO ;
c) Observe Flare A (four observations, one for each time signal) ;
d) Observe RO ;
e) Observe Flare B (four observations, one for each time signal) ;
f) Observe RO ;
g) Observe Flare C (four observations, one for each time signal) ;
h) Observe RO ;
i) Reverse telescope ;
j) Observe RO ;
k) Observe Flare C (four observations, one for each time signal) ;
l) Observe RO ;
m) Observe Flare B (four observations, one for each time signal) ;
n) Observe RO ;
o) Observe Flare A (four observations, one for each time signal) ;
p) Observe RO.

22.—The above procedure constituted one complete arc or circle position, referred to by the Danes and Norwegians as a " full set ". A " half set " meant a complete round with the telescope in one position.

23.—As much as 12 runs from A to C and C to A were carried out on some nights, thus giving 6 arcs for a night's work. Details of the flying and time signals broadcasted are given in Sections V and IV respectively.

24.—Angle comparison from two instruments at one station, when reduced to centre, gave variations up to 20 seconds of arc (Sexagesimal) for the earlier observations; but when the observers settled down to the job, this figure lessened to a maximum of 7". All of the observations have not yet been abstracted and analysed but this value was the maximum of those observations so far examined. The figure is very good considering that it represents one reading for each instrument on a moving flare, the pointing having been made at the instant the time signal was broadcasted. This error represents that of observation, instrument as well as personal errors of the observers.

25.—Details of the stations observed at are as follows :—

(a) NORWAY.

	Latitude	Longitude
SKIBMANSHEI (Primary and Laplace)	58°01'11".323	7°03'35".521 E/G
Azimuth to RO, Stoelsknipien	26°06'21".8	
	Latitude	Longitude
SOTAASEN (Complementary)	58°07'25".84	8°08'16".25 E/G
Azimuth to RO, Roksheia	354°07'36".4	
	Latitude	Longitude
HOVDEFJELL (Primary and Laplace)	58°42'09".754	8°39'45".374 E/G
Azimuth to RO, Knutsknat	321°26'40".0	

(b) DENMARK.

	Latitude	Longitude
HANSTHOLM (Complementary)	57°06'36".754	8°38'59".931 E/G
Azimuth to RO	310°41'45"	
	Latitude	Longitude
LERUP (Primary)	57°07'11".585	9°25'03".999 E/G
Azimuth to RO	322°34'59"	
	Latitude	Longitude
MYGDAL (Primary)	57°32'04".157	10°02'25"902 E/G
Azimuth to RO	229°49'34"	

26.—The stations observed to over the sea were :—

	Latitude	Longitude
A	57°30'	7°59'
B	57°43'	8°43'
C	57°57'	9°35'

27.—In Norway all stations were situated on hill or mountain tops with clear all round visibility. But in Denmark two towers were built at each station, one for each instrument.

IV.—SIGNALS.

28.—A radio receiving and transmitting station was set up at or near each of the six observing triangulation stations.

29.—The broadcast station was situated at Lerup, which was selected by virtue of its nearness to Aalborg, as the control station for all operations. Situated at this station was also a R.A.F. radio receiver and transmitter known as a VHF set. This set was erected inside the same vehicle in which the broadcast set was in. The VHF set kept one in direct communication with the pilot in the air as well as flying-control back at the airfield at Aalborg. There was also a special land line connexion to Aalborg airfield which proved very useful when our own VHF set broke down or when the flying-control set was US (Unserviceable).Observations would have ceased on nights when this happened if it had not been for this land line, for then it was possible to relay messages from flying control to the aircraft or from us at Control Station to the aircraft via flying-control.

30.—There was also a rear link to Regimental Headquarters in Germany. From the administrative point of view this was very useful and messages to Shaef or the War Office could be cleared from any one of the signal stations at the observation points.

31.—The time signal broadcast was a simple one and little or no alternation was made from that originally drawn up. Time signals were not of course broadcast at specified times but.when the pilot signalled his warning of approach and drop of flare. An example is given as follows, assuming a flare to be dropped at station A :—

AIRCRAFT	Broadcast signals	Time
Aircraft at point one minute's run from A, pilot signals : " Warner Able "	Series of	h. m. s.
	.— (A's)	0 00 00
	.— (A's)	
	.— (A's)	
	etc.	0 00 20
Aircraft at A drops flare, pilot signals : " Target Able "	Series of	
	—..— (X's)	0 01 00
	—..—	
	—..—	
	etc.	0 01 54
	Time Signal —.	0 02 00
	Series of (X's)	
	—..—	
	—..—	
	—..—	
	etc.	0 02 52
	Time Signal —..	0 03 00
	Series of (X's)	
	—..—	
	—..—	
	—..—	0 03 51
	Time Signal —...	0 04 00
	Series of (X's)	
	—..—	
	—..—	
	—..—	0 04 49
	Time Signal —....	0 05 00

NOTE.—The last dot in all cases is the time signal when observations from all stations to the flare are made. In the event of a " dummy " run, i.e. when flares failed to ignite or fall straight into the sea because the parachutes failed to open, then a series of dots was transmitted to indicate that a new run would be made at that point.

32.—The delay between the time the pilot's signal " Target " and the time the parachute flare opened and ignited was not more than 8 seconds. There was practically no delay between " Target " and the transmission of X's as the pilot's speech was heard distinctly in the headphone of the VHF set and the operator on the broadcast set would immediately transmit his warning signals consisting of X's.

33.—Speakers or headphones were provided for each observer at every observing station. In Denmark, at all stations, the broadcast signals were very clearly heard and at no time did they cause the observer to miss the observation because of faulty reception; in Norway, however, owing to the automatic transmission of a radio beacon using the same frequency, considerable interference was caused and a large number of observations were missed on that account.

34.—A system of radio watches was put into force and maintained. This was done so as to warn all observing parties up to the last moment regarding the possibility of making observations. The daylight hours were usually taken up for passing administrative traffic; i.e., reports on the previous night's work, meteorological reports and so on.

35.—Signal watches, or times when all stations were manned ready to receive and transmit signals were as follows :—

Hrs. D.B.S.T.	
1000	Transmission of previous night's observations reports, meteorological reports, administrative matters, etc.
1600	Proposed night's programme observations. Administrative signals, etc.
2000	Stand-by signals, tuning and last minute orders to all observing parties.
2200	Beginning of broadcasts. Reception from all stations after a complete run of aircraft from Sea Stations A to C of what flares had been observed and the number of shots taken on each.
0400	Usually the time when operations ceased for the night and all stations closed down.

V.—FLYING.

36.—The R.A.F. provided 9 Wellington bombers for the job, complete with flying and ground crews as well as flying-control.

37.—The usual flying procedure was for an aircraft to fly from A to C, dropping yellow flares at A, B and C; then, to orbit at C and return to A, dropping flares at C, B and A. A second aircraft was timed to take off from the airfield so that it arrived at A about 10 minutes or so after the departure of the earlier aircraft and repeated the same procedure. The maximum number of runs ever carried out in one night was 6 complete runs, A to C and back to A; or, in other words, 12 runs A to C and C to A.

38.—Before the commencement of the serious observations, experimental flights were made in order to determine the best flying procedure, height at which flares were to be dropped and type of flares. Also to decide whether to observe at nitght or by day. As a result of these test flights, it was decided to fly at night, dropping yellow flares at 8,000 feet height.

39.—Originally it was decided to drop green flares as "warners" (See para. 31), about one minute before the yellow target flares were dropped at sea stations A, B, C. But these were discontinued later because the green flares were not always seen. This was on account of the low brilliancy of the green flares which are something like 30,000 candle-power, whereas yellow flares are 230,000 candle-power. Also, it is possible that, as the particular part of the sky looked at where the flares were dropped was in the green band of the spectrum, this acted as a filter and so assisted in cutting out visibility of the green flares.

40.—Flares were dropped at 8,000 feet above the sea and the parachutes opened and the flares ingnited at about 7,000 feet. This appeared to be the best height for average meteorological conditions and, moreover, no striding level adjustments were necessary owing to the very low vertical angle (*). There were nights, however, when a thick bank of cirro-stratus intervened between the flares and the observers and then it was necessary to put into operation—ad hoc—a system of directing the pilot by R/T at what height he should release the flares, usually about 1,000 feet above the cloud base. This system worked very well.

41.—On some nights a brown heat haze developed, making it appear that the flares would not be seen; but the yellow flares showed up very well through this and no trouble was ever experienced in picking then up, even with the naked eye.

(*) This would give a vertical angle from a maximum of 1 ¼° to nearly zero.

42.—Generally, the yellow flares behaved very well, giving a very brilliant light seen easily 150 miles away with the bare eye. On very clear nights the flare was really too brilliant for good observations; the flares as seen through the thick brown haze being the best to sight on.

43. On nights when there was a strong upper wind (about 60 m.p.h.) crosswise to the line of sight, the travel of the flare was considerable, being about 25 metres per second; but, these conditions were exceptional and on some nights the movement was so slow that it was almost like observing on a fixed light.

44.—With the exception of a few early observations made in daylight, it was found best to observe at night owing to weather conditions, as by nighfall the usual daylight accumulation of cumulus clouds would have dissipated or reformed into banks of stratus, below the height at which the flares were observed to.

45.—The yellow flares used were the standard R.A.F. signal flares which usually lasted about 4 ½ minutes from the time of ignition. Occasionally they did not last beyond three minutes so that four observations on one flare was not possible.

46.—There were many occasions when the flares dropped straight into the sea as the parachutes seemingly failed to open.

47.—The instructions given to the pilots regarding the accuracy of position of the drop of flares was ± 2 miles from the given positions of A, B and C. Some checks made of this indicated that the pilots could keep to this specified accuracy provided that conditions were favourable and the Radar stations in operation.

48.—It did so happen on a few occasions when Radar was out of action that our own method of controlling the navigation of the aircraft had to be put into operation. This gave more accurate locations than the Radar fix once the pilots got into the 'swing' of things (See para. 49).

49.—At first, navigation by Dead Reckoning was followed by the pilots; but this resulted in very large errors of position up to nearly 30 miles and in some cases the flyer actually losing himself. A method of fixation from the ground was immediately put into operation: this consisted of detailing the observers on the Zeiss and Wild instruments at the Danish Stations Hanstholm, Lerup and Mygdal to immediately report by signal to the Control Station the true bearings of the flare as soon as seen. The bearings were received at the Lerup Control Station by signal and the writer then plotted the bearings on the control chart and called the pilot direct, indicating his bearing and distance away from true position of the station at which the fiare should have been dropped.

50.—This information reached the pilot from 1 to 4 minutes after the flare had been dropped and in time to correct his course and distance to the next position, since it usually took about 10 to 15 minutes to fly from one station to the other.

51.—Transport and supply of fuel and spares for the aircraft was quite a problem as the German Luftwaffe fuel found in the tanks on the field (Aalborg West) was found to be unusable. Some 50,000 gallons of 100 octane petrol was used in the course of the flying operations.

52.—It usually happened that only three of the nine Wellington would be available for the night's operations, the others being serviced and tested under the very rigorous R.A.F. regulations for maintenance of aircraft; or, perhaps, on transportation duties for urgent supplies to and from Holland at Wing H.Q.

53.—In addition, the writer paid almost daily visits to Norway as well as visits to the Geodetic Institute in Copenhagen. All these journeys were done by Wellington. This is mentioned so as to stress the necessity for a large number of aircraft if the job has to be done swiftly and with a rigorous standard of safety such as is required by the R.A.F.

54.—Very fortunately, the job was finished without incurring any loss of life or injury to personnel, although on the last day of flying one Wellington crashed on taking off and was a complete write-off. Also, owing to the healthy climatic conditions in Denmark and the social amenities such as sea-bathing and generous hospitality extended to the troops by the Danes, sick casualties were well below those existing normally at R.A.F. Stations.

55.—Arrangements were made with the Air-Sea-Rescue Unit stationed at Christiansand in Norway to keep track of our aircraft whilst on night flights over the Skagerrak in the event of forced landings. The pilot was able to keep in touch with them whilst in flight. Unfortunately their equipment consisted of an RDF set, giving a bearing **only.**

56.—A further safety precaution taken by us was to keep all available aircraft ready to go out to a plane that had force-landed on the sea and to drop float-flares on it as a guide to the Air-Sea-Rescue launches. The distressed plane was to jettison all flares at once as a signal to the observers on land that it was about to come down in the sea.

VI.—COMPUTATIONS.

57.—No computations other than preliminary ones of 11, 9 and 7 coordinations of the sea points A, B, C respectively have been done for test purposes only, merely to get an indication of the probable accuracy of a fixation. The results show that the value of one fixation, i.e. one shot on one flare from all stations, is correct to about ± 5 metres.

58.—The computation scheme carried out for this purpose was : firstly, to convert both Norwegian and Danish geographical coordinates of all the land stations to rectangular coordinates on North European Zone III grid.

59.—Next, from these rectangular coordinates the rectangular coordinates of a series of flares at A. B and C were computed from the Danish side and from the Norwegian side. Thus, two sets of rectangular coordinates for corresponding identical flares at A, B and C are obtained, one in terms of the Danish triangulation and the other in terms of the Norwegian.

60.—The difference indicates the difference in origin of the two stations(1). If there are no scale and rotation errors in the two triangulation systems then, excepting small errors of observation, this difference should be constant at A, B and C.

61.—The corresponding mean of the differences(2) of rectangular coordinates of the stations A, B, C will of course give a fair indication of the change in origin as well as change of scale and swing in azimuth of the two triangulations. Also, the difference from mean will also give a reasonable indication of the accuracy in fixation for each shot or flare.

62.—As stated in para. 24 above, the angle comparison of the Satellite stations indicates a reasonably good accuracy of angular determination. This angular error, reaching a maximum of 7", may be accountable by the fact that some observers would anticipate the time signal in the intersection of the flares whilst others would perhaps be late, bringing the cross-hair on to the flare after the time signal. As the maximum rate of travel of a flare was assessed as 25 metres per second, corresponding to an angular displacement of 63", a difference of 7" in arc between the readings of two observers (neglecting instrumental errors etc.), would indicate a difference in time of about 0.1 s.

63.—The manner in which the final computations are done depends to a large extent upon the way the major triangulation systems of North West Europe are treated to form a solid homogeneous block of triangulation.

64.—As far as can forseen at present, the connexion of the Norwegian and Danish nets across the Skagerrak should be computed as an extension of the new Danish triangulation in Jutland(3). Scale(4) and azimuth of the Norwegian triangulation should be retained as fixed conditions in any adjustment of the connecting net.

65.—The Norwegian net could then be re-worked so as to form part of the Danish chain, the whole to form the Western Component of a Scandinavian block

(1) This appears to be about 154 metres in easting and 172 metres in northing, which is remarkably close.
(2) Norwegian minus Danish.
(3) Itself forming an extension of a major European block of first order triangulation.
(4) Making any allowance for linear standards of length.

including Sweden, Finland and the Latvian States contiguous to the new German first order triangulation in Poland and East Prussia.

66.—Perhaps the simplest way of computing the connexion is, firstly to solve all the triangles for length and azimuth, from both sides of the Skagerrak. Next to compute the latitude and longitude in Danish terms for each flare dropped at the sea stations A, B, C. Finally, to calculate the latitude and longitude of each of the Norwegian Stations from the sides and azimuths computed from the Norwegian side and the latitude and longitude of the flares calculated from the Danish side.

67.—Each set of geographical coordinates of each of the Norwegian Stations would be weighted according to the observers' remarks on the observation lists and the total meaned accordingly(1). Final adjustment should then be made so as to retain the original Norwegian lengths and azimuths between the stations.

68.—The intentions of the Norwegian and Danish Institutes were each to compute the connexion net as an extension of their own national net. The results would be promulgated in their respective technical papers and in due course demands should be made upon them for these papers.

VII.—CONCLUSIONS.

69.—Even though the final computations have not been effected it has been shown that the triangulations of two countries, or systems, can be effectively and successfully joined by the method described above.

70.—The question of accuracy is one that depends on the number of observations that can be carried out economically. It is possible that an assessment of costs may show that it might be more economical to join a wide gap by the above method rather than by the more orthodox ground methods, particularly in areas such as the Sudd region of the Sudan. Wide stretches of desert country such as the Sahara and the great sand deserts of Tripolitania, Cyrenaica and Lybia could be spanned more economically by this new method. Also in archipelagos, where distances separating the islands are very great.

71.—Also, some of the classical meridian and parallel arcs of triangulation could now be extended and joined by this method instead of leaving them unfinished—an undulfilled dream and ambition of the geodesist. Possible connexions in this part of the world are(2) :—

(a) Italy-Corsica (the present connexion is not worth much) (130 miles) ;
(b) An extension of above (para. 71a) to Sardinia and Tunisia and so on into Africa proper (160 miles) ;
(c) Italy-Sicily-Tunisia (200 miles) ;
(d) Greece-Crete-Cyrenaica (100 and 240 miles) ;
(e) Turkey-Cyprus-Egypt (80 and 270 miles) ;
(f) Shetland and Orkneys-Norway (300 miles).

72.—Given good weather it should be possible to bridge gaps of 400 miles with ease, with equipment and methods such as were used in the Denmark-Norway connexion.

73.—In lieu of aircraft, parachute flares could be projected upwards from sea craft, by means of rocket apparatus. In the case of long spans such as 400 miles, then the rockets would have to project the parachute flares up to a height of at least 28,000 feet. Projectors such as used by Z Batteries R.A. would perhaps be suitable.

74.—Experience gained in this Survey has shown, where the use of aircraft is involved, that a very efficient meteorological service is a necessity. We went to

(1) Some 160 values should be available for each of the stations A,B and C. As the probable error in each coordinate is ± 5 metres (See para. 57) this indicates that the final results will be of a high accuracy.

(2) Since this paper was written the writer has visited the United States and plans are being made for extending the 1st order net in Florida to South America via the Bahamas and the Lesser Antilles, another loop passing from Florida to Cuba and across to Yucatan. Jamaica and Santo Domingo being linked in the general scheme. An extension of the triangulation to link up all the Aleutian Islands was also contemplated as well as the linking of all the Japanese Islands to the mainland.

a lot of trouble to set up an efficient meteorological service which involved making arrangements with the existing Danish and Norwegian meteorological service to keep us informed with their latest observations made along their respective coasts of the Skagerrak.

75.—Also, a very essential service is a good signal service. Efficient as our Royal Signals units were, there were times that direct communication by speech instead of morse would have quickened the pace and saved some wastage of time and material. If at all possible, radiotelephonic sets should be installed at all the observing stations; this point cannot be stressed too highly.

76.—Another service that should be provided is a navigation service for the fixation of the aircraft. We were fortunate in being situated just north of a "Gee" radar chain which had been previously established for R.A.F. navigational purposes and successful use was made of these stations, an aircraft being able to fix itself to about one mile in position.

77.—There was a stage when this service failed owing to a change-over of instruments. We then had institute our own system of aircraft fixation described in paragraph 49. This worked very well and in the absence of Radar, which, if very convenient, is rather a luxury, could very well be introduced at the outset.

78.—Sleep is a great essential. On the whole everybody got an adequate amount of sleep excepting the writer and the ALO (Air Liaison Officer) who sometimes acted for his. The writer found that usually he got about three hours sleep in 24 hours, which is not enough. The night hours were taken up in directing the observing and the daylight ones in travelling and administration. Arrangements should be made at the outset to have a good second-in-command to help in these duties.

79.—In allocating frequencies to the radio stations, if at all possible, a band should be chosen that is free of traffic by other stations at the particular times it is proposed to observe. Jamming by another station (an automatic radio beacon) in Norway was very troublesome and a number of observations were lost as the time signal was submerged in its strong and persistent signals, that was maddening to the observers to put it mildly.

80.—A decision will have to be taken, probably based on experiments, whether to work by day or by night. There is little doubt that night observations, from the climatic and instrumental points of view are preferable. Where aircraft are involved, however, it complicates the arrangements as special provisions must be made for night flying and to obtain pilots who are trained to fly at night. We were lucky in getting an R.A.F. detachment whose "metier" was night reconnaissance from the air. If ships are used, or the gap to be bridged is on land, then this problem does not arise.

Appendix A

CROSS CHANNEL CONNEXION, OBSERVING PROGRAM.

1.—Five balloons will be used as stations and will be towed by 5 MLS.

2.—ML's will be put into their predetermined stations by Radar, there—from steaming a steady course and speed—latter will be about 1 knot *over the* ground. Vessels will steam against tide so as to minimize yawing about of balloons. Tide estimated to run easterly 3 knots, so that general course and speed of ML's will be westerly, 4 knots.

3.—Total length of time will be 2 hours 2 minutes as per schedule below. There will be 21 minutes observing time per station. This should allow 4 arcs being observed, each arc taking about 5 ½ minutes : two faces to be observed per arc and it is possible that 2 pointings can be made on each face.

4.—Time will have to be observed for each pointing, using chronometer and stop watch. Chronometer to be rated on GMT by BBC six dot time signals. Detail of signals will be notified.

5.—There will be 3 minutes time available for picking up the next station (balloon) between observations and it is suggested that a second theodolite be set up near the observing one so as to pick up the second station; this second theodolite to be oriented the same as the first so that the direction can be called out and set on the first instrument.

6.—Each face observed must start on RO and close on RO.

7.—The following is a schedule of times during which the ML's will operate and the balloons flown (times given are GMT) :—

Station	Amended Times			
1	From	1530	to	1552
2	»	1555	»	1617
3	»	1620	»	1642
4	»	1645	»	1707
5	»	1710	»	1732

CROSS - CHANNEL OBSERVING AND BALLOON STATIONS

	Lat.	Long. W.	Ht
ENGLAND :—			
Ditchling	50°54'04"	0°06'20"	813
Dunnose	50°37'04"	1°11'50"	764
Carriegdon	50°37'47"	1°59'18"	655
Blackdown	50°41'10"	2°32'52"	777
FRANCE :—			
Bayeux	49°16'34"	0°42'15"	396
Mt-Etolan	49°39'15"	1°23'20"	450
Flottemauville	49°37'53"	1°44'20"	590
Yvelin	49°40'25"	1°51'10"	630
CHANNEL (Balloon Stations) :—			
Station (1)	50°04'50"	0°24'10"	—
Station (2)	50°06'00"	0°51'00"	—
Station (3)	50°07'30"	1°17'30"	—
Station (4)	50°09'00"	1°45'00"	—
Station (5)	50°11'00"	2°12'10"	—