FINAL VERSION

SUMMARY OF DISCUSSIONS

OF THE

FOURTH MEETING OF THE NAT SYSTEMS PLANNING GROUP

(Paris, 17 - 28 June 1968)

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INTRODUCTION

1. The Fourth Meeting of the NAT Systems Planning Group was held in the European Office of ICAO in Paris from 17 to 28 June 1968. On 17 June in the morning, on 26 June in the afternoon and on 28 June in the morning the Group met in closed session to discuss Agenda Items 6, 7 and 8 except those parts of Item 7 on which it had previously been decided that they would be dealt with in open session. During the remainder of the meeting the participants listed on page iv could fully participate in the proceedings. Portugal, which had been invited to participate in the meeting, had sent no representative.

2. Mr. J.F. Sapin, the member designated by France acted as chairman of the meeting. Two sub-groups were established, one to deal principally with operational matters (Items 1, 2, 3, 4 and 5) and one to deal with mathematical/statistical matters (Items 1 and 4). Mr. E.B. Powell from Canada was elected chairman of the operational sub-group and Mr. J. Villiers from France, chairman of the mathematical/statistical sub-group.

3. Mr. P.G. Berger and Mr. A. Azzaoui, both from the European Office of ICAO, served as secretaries of the meeting. Mr. F.E. Sperring from the Paris Office participated in the discussions on Item 2 in order to provide COM advice.

AGENDA

Item 1 : Review of the results of the data collection programme regarding navigational capability of aircraft in the NAT Region and their application to lateral separation.

Item 2 : Review of the situation concerning the continued operation of Loran A chain Charlie.

Item 3 : Assessment of the effectiveness of the new air reporting procedures applied on a trial basis in the NAT Region.

Item 4 : Development of a method for the determination of longitudinal separation standards in the NAT Region.

Item 5 : Exchange of views on a possible work programme of the NAT/SPG regarding SST operations in the NAT Region and development of a programme of preparatory measures, as necessary.

Item 6* : Review of the future work programme of the Group.

Item 7* : Any other business.

Item 8* : Election of the next Chairman.

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* Reserved for consideration by members of the Group only with the exception of a few specific subjects raised under Item 7.

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Note: Names marked with an asterisk are those of Members of the Group.

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GENERAL MATTERS

1. Presentation of studies made on vortices by Canada and the U.S.A.

1.1 Further to the presentation made by the U.S. member at the Third Meeting of the Group, he now made again available a film and data on further experiments which had been jointly conducted by Canada and the U.S.A. in order to study the development of vortices created by aircraft and their effects on other aircraft. (See also para. 1.4.2.6 of the Summary on Agenda Item 1.)

1. Summary of Agenda Item 1 : Review of the results of the data collection programme regarding navigational capability of aircraft in the NAT Region and their application to lateral separation.

1.1 Introduction

1.1.1 At its third meeting, held in April 1967, the NAT/SPG had developed the detailed arrangements for a data collection and analysis programme regarding navigational capability of aircraft in the NAT Region. The purpose of the programme was to:

i) enable a decision to be taken on the standard lateral separation to be applied in the NAT Region;

ii) identify causes of large deviations;

iii) determine the existing level of navigational capability.

1.1.2 The data collection programme was carried out in the period between July 1967 and March 1968 and, thanks to the cooperation of all the provider States and the large majority of users, yielded a considerable amount of data which, after analysis by the Royal Aircraft Establishment (RAE) of the United Kingdom allowed the Group to draw valuable conclusions.

1.1.3 For its deliberations of Agenda Item 1 the Group was provided by the United Kingdom with a preliminary report of the RAE containing a provisional summary of the results obtained from the programme, as well as a study on estimates of collision risks associated with lateral separation standards for subsonic turbo-jet aircraft in the period 1969-1974 and a study of traffic packing for estimating mid-air collision risks over the North Atlantic (RAE Technical Report 68097). These three papers served as a basis for the discussions of the Group both as regards its operations and mathematical/statistical aspects.

1.1.4 The Group noted with appreciation the fact that the United Kingdom was prepared to make available, through the ICAO European Office to all NAT States a final report of the data collection exercise as soon as this had been completed.

1.2 Description of the data collection programme

1.2.1 The data collection exercise was carried out by using two distinct methods :

i) at specific dates to request all flights to submit a specially prepared form (Form 1-D) on the performance of the flight ;

ii) during specified periods to observe the performance of all flights by means of radar and to relate these observations to the appropriate ATC data.

1.2.2 With regard to i) above this method was applied on 18 - 20 July, 18 - 20 August, 18 - 26 September, 18 - 20 October, 18 - 20 November and 18 - 20 December 1967. The total amount of Forms 1-D submitted were nearly 6000 for a total of 6606 flights conducted during the periods in question. This means that roughly 90 % of all flights complied with the data collection programme while 671 flights have not submitted the required forms.

1.2.3 The air navigation environment during the programme was that normally existing in the NAT Region except that Loran A chains "Charlie" and "Delta" were operating continuously during the early part of the programme. The former reverted to intermittent operation on 1st December 1967.

1.2.4 As regards the second method, i.e. the observation by radar, the following stations were used during the periods indicated :

Name	Latitude N	Longitude W	Period of observation
Kilkee (Manual)	52° 38'	09° 45'	1 July - 11 October 1967
Kilkee (Automatic)	52° 38'	09° 45'	15 September - 24 September
Gander	48° 55'	54° 30'	18 September - 29 November
Humboldt	57° 56'	35° 34'	27 September - 9 October
Cook Inlet	52° 43'	35° 33'	21 September - 6 October
Casco	47° 45'	35° 30'	21 September - 8 October
Humboldt	43° 45'	18° 30'	8 November - 27 November

The approximate area of cover for each of the radars and the number of observations, together with the period of observation are shown in Figure 1.1 attached to this summary. It should also be noted that the positions of the ships are approximate since they are not fixed but move slowly in the neighbourhood of a nominal position. (For the compensation of the difference between the actual and the theoretical position see the Summary of the 2. Meeting of the NAT/SPG, Appendix 6-B and more specifically para. 6.1 of that appendix).

1.2.5 From these radars the following numbers of observations have been obtained :

Position of radar	Direction of flight	
	Eastbound	Westbound
Humboldt 1) Ships at 35°W	283	755
Cook Inlet) Ships at 35°W	1215	800
Casco) Ships at 35°W	414	210
Humboldt 2 at 18°W	133	135
Kilkee Manual observations	7400	-
Kilkee Automatic observations	1017	-
Gander	-	2442

Note : The total number of independent observations made by the three ships at 35°W was 3338.

It should however be noted that some flights were observed by more than one of the ship's radar stations because their area of cover overlapped. As a consequence, th- total number of individual flights observed is slightly less than the total of observations obtained by the various radar stations.

1.2.6 The Group decided that the results obtained by the data collection programme should be reviewed under both the operational and the mathematical/statistical aspect in order to draw the necessary conclusions and the results of the findings are given hereafter.

1.3 Operational review of the results of the data collection programme

Determination of number of large deviations

1.3.1 The Group agreed that, when reviewing the results of the data collection programme from the operational aspect, its first task would be to establish how many errors exceeding a specified limit had been reported (in the case of the submission of Forms 1-D) or observed (in the case of radar observations).

1.3.2 In the case of the reporting by use of Form 1-D (which covered nearly 6000 flights) it was noted that there were 203 cases for which operators had reported apparent deviations from the assigned track of 30 NM or more. Operators had also been requested to provide a reason, if possible, for any deviation exceeding 30 NM or more and from the information provided on the Forms 1-D submitted by operators these causes were classified as follows :

Cause	Number
Poor Loran reception	25
Doppler malfunction	8
Compass malfunction	9
Weathership misguidance	2
Met. forecast winds	17
Weather avoidance	3
Crew errors	36
Crew under training	30
Miscellaneous	30
None	43

Note : In cases where more than one reason was given each of them was assumed to have equal weight. For example if "poor Loran reception" and "Doppler malfunction" were both given, each would be regarded as causing "half a large deviation" for the purpose of compiling the above listing.

1.3.3 As regards the radar observations, it was found that out of the total of nearly 15000 observations there were 143 cases where deviations from the assigned track 40 NM or more were observed. 89 of these concerned cases where a deviation of 45 NM or more was observed. It should however be noted that, since many of these observed cases occurred at times when the data collection programme by means of Form 1-D was not applied, there is not direct relationship between the 143 cases mentioned in this paragraph and those referred to in para. 1.3.2 above.

1.3.4 In view of the time and effort involved, it has not been possible to provide for a complete and detailed presentation of all radar observed errors. However a summary presentation is given in Figure 1.2.

1.3.5 In addition it was believed that a presentation of the situation as observed by means of the three ship-borne radar stations located at 35°W would be of particular interest.

1.3.6 In addition it was pointed out that, whenever a radar-observed deviation of 40 NM or more from the assigned track occurred, the operator concerned was requested to provide a Form 1-D for the flight concerned, even though this had occurred outside the periods during which operators were required to provide such a form on a routine basis. It should therefore be noted that the majority of these Forms 1-D are not included in the numbers mentioned in paras 1.2.2 and 1.3.2 above.

1.3.7 The radar situation observed at 35°W is shown in Figure 1-3 and for those flights exceeding an observed deviation from the assigned track of 45 NM or more the information provided on the Form 1-D requested in accordance with the provisions mentioned in para. 1.3.6 above are given as far as these were made available.

1.3.8 As regards the total of the 143 cases of radar observed deviations (see paragraph 1.3.3) the information provided by operators by means of Form 1-D in accordance with para. 1.3.6 gave the following results :

Note : It is recalled that the figures shown in the column marked "cases exceeding 45 NM" are included in the figures shown under "cases exceeding 40 NM".

	Cases exceeding 40 NM	Cases exceeding 45 NM
Number of cases	143	89
- Form 1-D not yet received from operator	40	30
- Form 1-D received but no deviation indicated	56	34

Note : It should be noted that Form 1-D only makes provision for the indication of deviations of 30 NM or more

- Form 1-D received and deviation acknowledged	47	25

1.3.9 For the 47 cases in which a deviation was acknowledged on Form 1-D, the reasons given for those were the following :

(Note : Where two causes have been given for the deviation, each of them was assumed to account half for the deviation)

	Cases exceeding 40 NM	Cases exceeding 45 NM
Misuse of equipment	4	2 ½
Poor Loran A reception	4 ½	4 ½
Doppler malfunction	6	2
Compass malfunction	1	1
Weather ship misguidance	1 ½	1
MET forecast winds	1 ½	-
Weather avoidance action	1	-
Crew under training	13 ½	6 ½
Miscellaneous	9	3
No reason given	5	4 ½

1.3.10 It should also be noted that more than 25 % of the radar-observed deviations exceeding 40 NM were caused by 14 "infrequent users" (i.e. operators which do not regularly fly in the NAT Region) who collectively constitute only about 8 % of the total air traffic in the NAT Region.

Review of large deviations

1.3.11 The Group, after having established the number of reported or observed large deviations, then proceeded to a review of the major causes for them and agreed that these could be classified in the following three broad categories :

i) environmental weaknesses ;

ii) equipment malfunctioning ;

iii) deficiencies in the operating techniques, both on board the aircraft and on the ground.

1.3.12 With regard to i) above the most noticeable causes appeared to be :

i) the lack of Loran A cover in certain parts of the area ;

ii) variations in Loran A cover due to radio propagation phenomena ;

iii) influence on raw doppler data by the state of the sea ;

iv) lack of reliability of indication of magnetic variations in parts of the Region;

v) lack of precision in MET forecasting.

1.3.13 As concerns the second category mentioned in para. 1.3.11, i.e. equipment malfunctioning, this was most frequently reported to concern the following equipment :

i) doppler ;

ii) Loran ;

iii) compass.

1.3.14 With respect to the third category, i.e. deficiencies in the operating techniques, the group was obviously not able, nor prepared, to review these cases in any appreciable detail since, in most cases, the information provided was not sufficient to accomplish this task with any reasonable degree of reliability. It was nevertheless noted that this category seemed to account for at least 70 % of all cases of reported and radar-observed large deviations and that by far largest part of them again could be attributed to deficiencies in operating techniques aboard the aircraft. (It should be noted that all those cases which were classified as "miscellaneous" or for which no reason at all had been given were considered to fall also in this category). Finally, the Group noted that within this category the largest single cause for large deviations could be attributed to those cases where one or more members of the flight crew in the cockpit were under training.

1.3.15 It was noticed that deviations on eastbound flights exceed the deviation on westbound flights. The cause was probably a combination of the following factors :

i) Loran cover on eastbound tracks was less extensive due to the tendency for eastbound tracks to lie south of westbound tracks ;

ii) because most eastbound flight were made at night, Loran operation was more difficult ;

iii) eastbound aircraft tend to seek jet streams and hence experience sharper wind changes less rapidly recognized by aircraft not doppler equipped ;

iv) because of the higher ground speed on eastbound flights a more rapid divergence from track occurs in the event of heading error ;

v) the fatigue factor makes itself more felt since these flights are, in the majority of cases, conducted at night.

1.3.16 Further, it was noticed that in mid-Atlantic deviations to the south of track were greater and more frequent than deviations to the north. A possible contributory cause was that most aircraft fly an average magnetic track between successive reporting points while deviations were assessed in relation to the great circle track between them. It was pointed out however that this effect was comparatively small.

1.3.17 As regards the 4 cases of deviations due to weather avoidance action (3 reported in the Form 1-D data collection and one in the radar-observation programme), it was noted that these appeared to present intentional actions on the part of the pilots concerned for which it had to be assumed that, for unspecified reasons they had been unable, at the time, to obtain prior ATC approval for such deviations as envisaged by the appropriate regional supplementary procedures. It would therefore appear that in these 4 cases the pilots concerned acted in accordance with the responsibility given to them by Annex 2 and that these cases could therefore, not necessarily, be classified in the same way as the others.

1.3.18 It was also noted that the data collection programme had revealed a direct relationship between the navigational accuracy obtained by aircraft in the NAT Region and the navigational equipment fitted on board these aircraft. This relationship is shown in Figure 1.4.

Measures to be taken for the improvement of navigational accuracy

1.3.19 When considering the measures to be taken in order to improve the navigational accuracy in the NAT Region, it was noted that a number of developments, both as regards self-contained navigation systems and external aids and improved ATC systems based on the use of satellites were being actively pursued. However it was also noted that some of these could hardly be available before the mid 1970's and that therefore any immediate improvement must be based on existing systems and facilities or those which are likely to become available within the next 3-5 years.

1.3.20 It was also noted that the continued retention of the present lateral separation standard must inevitably contribute to the increase in traffic delays and routing penalties already being experienced. On the other hand, the data collection programme had clearly demonstrated that there was a small minority of operators which contributed disproportionately to the number of large deviations from the assigned track (see para. 1.3.10). Since in any system, the general criteria have to be adjusted so as to cater for the weakest link in the chain, it would therefore appear that this situation, if not improved, could lead to a point where the majority of operators, who have concentrated their efforts and considerable capital investment in improving their capabilities to the point where these meet more stringent requirements, will continue to be deprived of the benefits of such efforts because of the lack of cooperation on the part of a small minority.

1.3.21 In view of this possibility, the Group agreed that it was necessary to take action in the following broad fields :

i) international and national requirements for operations in the NAT Region ;

ii) measures to improve navigation performance ;

iii) measures to eliminate deficiencies in operating techniques.

1.3.22 With respect to i) above the Group noted that the international requirements which define the navigational capability are contained in Annex 6 of ICAO. They can be summarized as follows :

i) The requirement for the carriage of radio navigation equipment are contained in para. 7.2 of Annex 6 and specify that aircraft operated in accordance with IFR shall be provided with radio navigation equipment to enable the aircraft to navigate:

a) in accordance with its operational flight plan, and

b) in accordance with the requirements of air traffic services.

In addition it is also specified that sufficient redundance in navigation equipment shall be provided to enable the aircraft to continue to navigate in case of failure of one item of the equipment provided.

ii) As to the requirement concerning the composition of the flight crew, para. 9.1.4 of Annex 6 specifies that "the flight crew shall include at least one member who holds a flight navigator license in all operations where, as determined by the State of Registry, navigation necessary for the safe conduct of the flight cannot be adequately accomplished by the pilots from the pilot station".

1.3.23 National practices in respect of the above requirements vary considerably. Some States evidently require the inclusion of a navigator in the flight crew regardless of the degree of sophistication of the radio navigation equipment available on board the aircraft while others make this requirement dependent on the type and performance of the radio navigation equipment installed by the operator in the aircraft and the operating techniques employed. In some other cases it appears that certain States of Registry leave this question to the discretion of their operators without legislative intervention.

1.3.24 While the Group recognized that complex legal and administrative problems might be involved, it would be worthwhile, in the longer term, to endeavour to obtain international definition of the navigational performance requirements for Oceanic Regions. It was considered that the existing requirement for equipment carriage, related to the needs of the ATC system now set out in Annex 6, was not sufficiently precise. It was agreed that a change in Annex 6 should be sought to meet the needs of the changing environment. In the shorter term it was hoped that the parties (States of Registry and Operators) concerned would voluntarily be prepared to review the practices and the need for equipment for operations in the NAT Region with a view to ensuring that a uniformly high degree of navigational accuracy was achieved.

1.3.25 With regard to paragraph 1.3.21(ii), in view of the results obtained in the data collection programme it appeared that navigation based on the use of doppler with a computer with celestial and Loran fixing, together with adequate flight deck management techniques has substantial advantages over other methods in use to-day. In one particular case, where two types of aircraft were operated by a single operator, one fleet doppler equipped, the other without, it was noted that the standard deviation measured by Kilkee (Auto and Manual) was 17.23 NM for the non-doppler fit and 11.27NM for the doppler equipped aircraft. However, it is important to point out that regardless of aircraft navigation equipment, optimum performance is dependent on effective maintainance and an adequate crew training programme. In addition, even though this had not been formally demonstrated, it is only logical to conclude that an autopilot coupling facility for the doppler with computer equipment does produce a further improvement in navigational accuracy provided this equipment is properly monitored by the flight crew.

1.3.26 As regards the provision of land-based radio navigation aids, the Group agreed that it will be absolutely essential that all existing Loran A chains in the NAT Region (including chains "Charlie" and "Delta") are maintained, or brought into full operational service if fixing accuracy is to be maintained. (For the operation of Loran A chains in the Eastern Atlantic and especially that of Loran A chain "Chairlie" see the summary on Agenda Item 2).

1.3.27 The Group confirmed the obvious requirement that aircraft should maintain their assigned track with as high a degree of accuracy as is compatible with the navigation equipment available and the cockpit workload involved. To ensure the optimum degree of compliance with the above requirement, the Group strongly recommends to States that in all cases where it is found that an aircraft had deviated from the assigned track by more than 20 NM, the State or the operator concerned should examine the need for corrective action in accordance with established national practices.

1.3.28 A procedure similar to that now used by Canada whereby radar observed deviations on a random sampling basis are reported to the State of registry and/or operator for investigation should be continued and extended to both the U.K. and Ireland using the criterion of 20 NM suggested in paragraph 1.3.27 above as soon as this is practicable.

1.3.29 In addition, the Group recommends that States and operator's organizations should bring to the attention of flight crews the need to comply with the requirement to maintain their assigned track as closely as possible and develop procedures, where necessary, to ensure continued compliance with this requirement especially in geographical areas where no ground bases radar monitoring facilities are available.

1.3.30 With regard to 1.3.21 iii), Measures to eliminate deficiencies in operating techniques, the Group felt that, because of the large variety of conditions existing in this field, it was not possible to make specific comments except on two aspects. These are :

i) maintenance of the assigned track ;

ii) the training of flight crew members.

1.3.31 With regard to maintenance of the assigned track, the Group believed that, apart from the relationship between the navigation equipment provided in the aircraft and the navigational accuracy achieved (para. 1.3.18 refers), there is also a correlation between track keeping and the frequency with which this is checked. It was noted that the improvements in position fixing techniques achieved in recent years by the increased application of automation to equipment read out and the resultant reduction in workload had a bearing on this question. Without going into the details of position fixing or track keeping requirements, the Group nevertheless believed it reasonable to expect that confirmative action regarding track keeping should be taken on board aircraft at intervals normally not exceeding 20 minutes.

1.3.32 With regard to the problem of en-route training of flight crew members, it has been shown in paras 1.3.2 and 1.3.9 that this accounted for an unwarranted large percentage of the total of large deviations reported or observed. Investigations suggest that deviations occurred when the trainee crew member was deliberately deprived of part of the navigation capability of the aircraft (e.g. Doppler equipment switched off or screened) and that, under these conditions, there was inadequate attention given to the possibility of deviation from track by the supervisory crew member or members concerned.

1.3.33 The Group therefore agreed that such practice should be discontinued and that, where required, training should be conducted in such a manner as to ensure that no degradation of the navigation accuracy will occur.

Significant changes to the navigation environment which have taken place since the data collection exercise

1.3.34 The Group agreed that, in order to come to a realistic appreciation of the existing situation, it would be essential to take account of significant changes which had occurred to the navigation environment in the NAT Region since the data collection exercise and that this could best be made by considering this under the following two broad aspects :

i) changes to the navigation equipment aboard the aircraft operating in the NAT Region ;

ii) changes to external or land-based navigation aids.

1.3.35 Since it has earlier been shown that there seemed to exist a close relationship between navigation accuracy and the availability of doppler navigation equipment aboard the aircraft (see figure 1.4) the Group agreed that it would pay particular attention to this aspect of i) above. It was noted that during the period of radar observations the situation with regard to the provision of Doppler equipment was approximately the following :

No Doppler equipment available	15% of all flights by jet aircraft
Doppler sensor available only	20% of all flights by jet aircraft
Doppler with computer available	65% of all flights by jet aircraft.

1.3.36 In the meantime, re-equipment programmes by a number of operators, started since the data collection exercise (see para. 1.3.25), continue with the effect that it can be safely said that, before the end of 1968 the situation will be the following, or better :

No Doppler equipment available	2% of all flights by jet aircraft
Doppler sensor available only	18% of all flights by jet aircraft
Doppler with computer available	80% of all flights by jet aircraft

1.3.37 The Group agreed that such changes in the environment should be taken into consideration since they constitute an element of considerable significance for present and future developments regarding lateral separation in the NAT Region.

1.3.38 With respect to 1.3.34 ii), changes to external or land-based navigation aids, the Group noted that there were two developments which deserved consideration. They are :

i) the changes made by the 6. North Atlantic Ocean Station Vessel Conference to the requirement for the carriage of radio navigation aids by Ocean Station Vessels;

ii) the operating status of Loran A chains "Charlie" and "Delta".

1.3.39 As concerns i) above it was noted that the 6. NAOS Conference modified the previous requirement for the carriage of Radar and NDB and VDF on board OSV's to one specifying that at least one of these three aids was required, however, in the preferential order of Radar, NDB or VDF. Nevertheless it had also become apparent during this conference that this modification was not likely to have any immediate practical consequences.

1.3.40 With respect to the operating status of Loran A chains "Charlie" and "Delta" however, the Group unanimously agreed that these constitued an essential element in the navigation cover provided in the NAT Region. It therefore believed that the administrations concerned should make every effort to overcome the present difficulties in order to ensure a 24 hours operation of these chains as of the earliest date possible and in any event not later than 19 September 1968. (See also the summary on Agenda Item 2)

1.3.41 Finally IATA informed the Group that, subsequent to Recommendation 6i/9 of the Special NAT Meeting 1965, specifying that operators examine their navigational techniques, IATA had already held meetings with a view to achieving improvements in this field. These meetings have had beneficial results and the subject is being pursued on a continuing basis.

1.4 Mathematical/statistical analysis of the data

1.4.1 Examination of the validity of the data

The Group examined first whether the data obtained from the various sub-areas was truly representative of the actual aircraft track-keeping capability over the NAT Region.

1.4.1.1 Kilkee data

1.4.1.1.1 The Kilkee data consists of : 1017 automatically recorded observations taken during September 15-25 ; 890 manually recorded observations taken during the same period (mostly on the same aircraft) ; and 7400 manually recorded observations taken during other periods. Figure 1.5, page 1-A .. compares the auto-recorded data with the 890 manually recorded data, and RAE stated that "difference between the two distributions is very small". The Group took this as confirming the validity of the manual recording process. However, the other 7400 manually recorded observations showed larger percentages of deviations, and therefore all of the manually recorded data were challenged.

1.4.1.1.2 It was agreed by the Group that the totality of the Kilkee data (8417 observations with 69 deviations over 45 NM) was the only source of data sufficiently large and homogeneous to yield information on tail shape, and that it was therefore desirable to retain these data. Objections to their validity fell basically under two headings : that the manual method might introduce large errors, creating large deviations where there were none ; and that the manual method might add small errors, increasing thereby the number of large deviations (for example, by raising a 44 NM deviation to a 46 NM deviation). In this respect, it was agreed that if a large manual error were made (for example, writing 256 for 265), it would almost always create a large deviation, and almost never cancel a large deviation. However, it was pointed out that the so-called "automatic" data had a large amount of manual processing, and that the "manual" data had been collected with much appropriate caution. It was therefore agreed to assume that the manual data was not biased by large measurement errors.

1.4.1.1.3 As for small errors, it was agreed that manual recording could not be as precise as automatic recording, and that small errors introduced in this way would, on average, introduce a bias such that observed deviations were larger than true deviations. However, for reasons discussed in para 1.4.1.6 it was decided that this bias was only one mile or less.

1.4.1.1.4 In the light of the foregoing it was agreed to accept the validity of all Kilkee Data.

1.4.1.2 <u>Humboldt II (southeast ship) data</u>

It was agreed to accept the validity of these data.

1.4.1.3 <u>Central ships (35°W) data</u>

It was suggested that, because of the existence of a beacon on the ship at 53°N, and because this ship provides radar fixes, some improvement in navigation of aircraft may be expected. However, since this ship is a permanent fixture in the NAT environment, the resulting data are representative of NAT navigational capability.

It was also suggested that some aircraft might receive such navigational assistance before the position was plotted, and that the data were therefore not representative of larger regions of the Atlantic. The Group agreed, however, that such occurrences are rare enough for them to be ignored. It was also noted that of the aircraft which might have been expected to be observed by the ship only about 94 % had actually been recorded. Failure of the ship's radar would account for some of the missing 6 %, but there was insufficient evidence to explain why others had not been recorded; in some cases, apparently, the transponder was unserviceable or switched off. In these circumstances, the Group decided to accept the validity of all data from the three ships at 35°W.

1.4.1.4 <u>Gander data</u>

1.4.1.4.1 Of the 2442 observations at Gander, 5 showed deviations greater than 40 NM, and 3 greater than 45 NM.

Objection to the Gander data was based on the possibility that the aircraft would :

a) receive land-based aids and

b) act on this information to reduce deviation, before the Gander radar measured it. If this had occurred, the observed deviations would, on average, be smaller than deviations occuring beyond radar cover.

1.4.1.4.2 In earlier experiments, objection had been taken on similar grounds to data from both Gander and Ulster radar. For the present experiment, the Ulster radar had been replaced by one at Kilkee, on the edge of the ocean and at an altitude of several hundred feet, while the Gander radar remained 50 NM from shore and nearly at see level. The Gander radar had an average detection range of 220-225 NM, and the average range of first automatic recording was 210 NM (160 NM from shore -- or less for aircraft at extreme latitudes). The VOR coverage of 235 NM at 35,000 feet was ascertained. ADF could be picked up at greater ranges (perhaps 300 NM)but it is doubtful that it could be used at such ranges.

1.4.1.4.3 It was agreed to investigate the correlation between Y (lateral deviation of actual track from ATC assigned track) and $\dot{Y}$ (the rate of change of this deviation). Previous correlation studies had been concerned only with $|Y|$ and $|\dot{Y}|$, that is, the absolute values of these quantities, without regard to sign (positive or negative). If the conjectured bias in the Gander data exists, there should be a negative correlation between Y and $\dot{Y}$; that is, large values of Y should be associated with $\dot{Y}$'s of opposite sign (convergence toward assigned track). By contrast, ship data should show a positive correlation ; that is, some convergence, but more divergence. It was agreed that if these correlations were not found, the validity of the Gander data would be accepted.

1.4.1.4.4 An examination of the five Gander tracks with errors of over 40 NM and of twelve auto-recorded tracks from 35°W showed correlations as described above. Of the five Gander tracks examined, three were apparently homing on the land-based navaid and therefore converging slowly on track, implying a small bias in the data. One was converging on track at about 30°, implying a large bias in the data.

Calculation shows that at Mach 0.8, an aircraft in a 12° bank changes heading by 30° in 75 seconds; and at 30° from track, reduces error by more than 4 miles per minute. It is thus possible to reduce deviation appreciably before radar recording. Whether pilots would be likely to do so was subject to disagreement.

1.4.1.4.5 2437 observations showed deviations of less than 40 NM; whether a few of these actually had deviations of 45 NM or more immediately prior to receiving land-based information would be difficult (perhaps impossible) to determine statistically.

1.4.1.4.6 It was therefore agreed that the Gander data did not have the same validity as that conceded for the data from the other stations. This is reflected in the treatment accorded to this data in para 1.4.3.1.3.

1.4.1.5 Form 1-D data

The Group was of the opinion that the lack of agreement between deviation information obtained from Form 1-D and that obtained by radar was disappointing . An attempt to further assess the relationship between these two sources might be left for future study by all concerned. For the time being, although the Form 1-D information relating to other than deviations had been essential to the work of the Group (as indicated in other paragraphs) it agreed to confine the analysis of deviations from track to data derived from radar sources.

1.4.1.6 Effect of measurement errors

1.4.1.6.1 Each recorded observation consists of the arithmetic sum (i.e., addition or substraction) of two errors : the actual navigational deviation and the total error introduced in measuring and recording. As indicated in paragraph 1.4.1.1.2, it was agreed to assume that large measurement errors have been eliminated by the FAA and RAE. The effect of small errors was subject to a mathematical analysis, and the following conclusion was reached : if the navigational deviations have standard deviations of the order of 11 to 16 NM, and if the measurement errors have standard deviations of the order of 2 to 3.5 NM, and if there are no biases on the measurement error (i.e., mean Zero), and if the tail shape lies between level and exponential, then the observed deviations are too large, probably by 1 NM or less, i.e., the true proportion of deviations outside 45 NM is probably about the observed proportion outside 46 NM.

1.4.1.6.2 While this discussion was motivated by the possible effect of manual errors at Kilkee, it applies to all the data. In particular, the number 3.5 miles above is derived from an empirical (not theoretical) estimate of measurement errors ; i.e. it happens that 325 aircraft were observed by two different ships at 35°W, giving two entirely independent estimates of position (see Table 1.6). These observations show remarkable agreement, with a standard deviation of 5 NM in relative error which, assuming independence, implies 3.5 NM for individual measurements. It is believed that average measurement error at all stations lies in the range 2 to 3.5 miles, with the smaller number being typical of auto-recorded data at Gander and Kilkee.

1.4.1.7 Inclination of tracks

A separation standard of 90 or 120 NM between adjacent track is, in practice, measured in a direction parallel to the N-S line. Thus, as indicated in Figure 1.7, the actual distance is reduced by the quantity Cos θ, where θ is the angle between the tracks and the E-W line. Many NAT tracks have 1° latitude change for 10° longitude change. This corresponds to 1 NM N-S for each 6. NM E-W, corresponding to $\theta = 1/6$ radian. Since cos 1/6 = 0.987, this implies that a nominal separation of 90 NM is actually about 89 NM actual separation. This correction approximately cancels the one from the above paragraph. However, the effect increases rapidly, and for tracks inclined at 2° latitude to 10° longitude, the collision risk could be greatly increased.

1.4.2 Review of various assumptions in the collision risk equation

1.4.2.1 The collision risk equation

1.4.2.1.1 During its second Meeting, the Group agreed that collision risks should be estimated using the equation :

$$N_{ay} = \frac{2 \times 10^7 P_y \text{ (std)}}{H} \left\{ \frac{T_y \text{ (same)}}{S_x} \left[\frac{\overline{\Delta V}}{2} P_z(0) + \overline{\dot{y}} \Lambda_x N_z(0) + \frac{\Lambda_x |\overline{\dot{y}}| P_z(0)}{2\lambda_y} \right] \right.$$

$$\left. + \frac{T_y \text{ (opp)}}{S_x} \overline{V} P_z(0) + \overline{\dot{y}} \Lambda_x N_z(0) + \frac{\Lambda_x |\overline{\dot{y}}| P_z(0)}{2\lambda_y} \right] \right\} \qquad (1)$$

This equation has been put in a slightly different form, as it was thought to be more convenient to replace $2T_y$ (same)/H by E_y (same) and $2T_y$ (opp)/H by E_y (opp) ; the E's are called "occupancies" and represent the average number of aircraft occupying segments of length 2Sx of the tracks, adjacent to the track and at the same flight level as the typical aircraft.

$$N_{ay} = 10^7 P_y \text{ (std)} \left\{ \frac{E_y \text{ (same)}}{S_x} \left[\frac{\Delta V}{2} P_z(0) + \overline{\dot{y}} \Lambda_x N_z(0) + \frac{\Lambda_x |\overline{\dot{y}}| P_z(0)}{2\lambda_y} \right] \right.$$

$$\left. + \frac{E_y \text{ (opp)}}{S_x} \left[\overline{V} P_z(0) + \overline{\dot{y}} \Lambda_x N_z(0) + \frac{\Lambda |\overline{\dot{y}}| P_z(0)}{2\lambda_y} \right] \right\} \qquad (2)$$

1.4.2.1.2 In this equation :

N_{ay} is the expected number of accidents per 10 million flying hours, due to failure of lateral separation.

H is the total number of aircraft flying hours during the period considered.

λ_y is the length of the collision slab.

Λ_x is the "effective" collision length of the collision slab after taking account of wing-tip vortices.

$P_y(std)$ is the probability that the across-track separation of a pair of aircraft, nominally spaced at the lateral standard separation, is less than λ_y.

$P_z(0)$ is the probability that a pair of aircraft assigned to the same flight level are separated in the vertical dimension by less than λ_z.

$N_z(0)$ is the frequency with which vertical separation of a pair of aircraft assigned to the same flight level shrinks to less than λ_z.

γ is a coefficient applied to the N_z terms to allow alternative models of the effective collision shape to be simply represented in the equation as rectangular slabs of constant cross-section $\lambda_y \lambda_z$ set by the metallic thickness and span of an aircraft.

$E_y(same)$)
) see para. 1.4.2.5
$E_y(opp.)$)

S_x is the along-track criterion of proximity.

$\overline{\Delta V}$ is the relative longitudinal speed between aircraft flying in the same direction (see para. 1.4.2.4)

$|\dot{Y}|$ is the mean relative across-track velocity of a pair of aircraft which has lost lateral separation.

1.4.2.1.3 The Group discussed the values which should be assigned to certain parameters in equation (2) :

1.4.2.2 The probability of lateral overlap, P_y(std)

1.4.2.2.1 In the determination of P_y, it is assumed that the distribution function of the lateral distance between two proximate aircraft can be derived from a convolution of the across-track deviation distributions of the single aircraft. In this process it must be assumed that the across-track errors of the individual aircraft are independant. The RAE provided some evidence from which this assumption could be tested (see figures 1-8 to 1-11). In case of independance, the curve for y should show values 1.4 times those of the across-track deviations, for the same values of the percentage of the observations. The Group noted that there was evidence that there was a slight positive correlation between the across-track deviations, but agreed that this would not be taken into account in the calculations. In this respect the model used is cautious.

1.4.2.2.2 With regard to the treatment of the tail shape and tail area of the across-track deviations, the Group agreed during its second meeting, that after the data were collected one of the 3 following possibilities might occur :

i) the area of the tail is so small that the separation standard under consideration can be judged "safe", regardless of the tail shape. The next step will then be to analyse smaller separation standards ;

ii) there would be so many large errors that an accurate judgement on tail shape will be possible ;

iii) the intermediate case where the data are not sufficient for a precise determination of risk without an assumption on tail shape, and where precise determination of shape is not possible. The Group decided at its second meeting that in this case a Monte Carlo procedure would be used, in which the effect of tail shape would be taken into account by taking at random values of P_y between its values for an exponential and for a level tail.

1.4.2.2.3 The Kilkee data resulting from the addition of the manual sample was found to contain sufficient observations of large across-track deviations to give useful inferences on tail-shape. However, at the other radar stations the samples were such less numerous and, in particular, observations on deviations exceeding 45NM were relatively rare. An analysis using some of the Kilkee radar data, showed that the method mentioned under iii) above would grossly overestimate the value of P_y (std) and therefore the estimated number of collisions. The results of this analysis are shown in Figure 1.12, page 1-A. The most probable value for P_y (std) from the Kilkee data would be that which was obtained by a direct convolution of the histograms. This gives the value labelled as "RAE central" in figure 1.12. This figure also shows the values for the exponential tail and for the level tail according to the method agreed at the second SPG Meeting (labelled "level (RAE)"). The Monte-Carlo process would have produced an effective value about half-way between exponential and level (RAE). This is shown in figure 1.12 as "NAT SPG". It will be seen that this value would be about twice that obtained by the RAE "central" method. The NLR of the Netherlands had proposed a modification of the NAT SPG-2 method. In this method the Monte-Carlo method between level and exponential was retained, but the method for determining the "level" upper limit was modified. The values for "level (NLR)" and for the effective mean value between level "NLR" and exponential are shown in figure 1.12. It will be seen that the NLR method provides a reasonably good approximation to the actual data, and the Group agreed that some realistic conclusions could be drawn from data analysed by the NLR method.

1.4.2.2.4 The Group did not, however, accept the NLR method for further use. This was mainly because this method would not lend itself to analysing distributions with very few data outside 45NM, which would be necessary for the analysis described in para. 1.4.3.

1.4.2.2.5 In seeking a natural model, the Group was led to examine analytic structures intermediate between exponential and level. It examined the form ax^{-n} where n is a small number, perhaps at the approximate magnitude4. This describes the cumulative function – the corresponding density function will be of the from $k.x^{-(n+1)}$.

It is proposed to carry out the following elementary analysis. The 69 large deviations (larger than 45NM) at Kilkee will be fitted to x^{-n} functions probably through least squares techniques, as follows : define x (in NM) as the error magnitude, Y as the number of deviations of this magnitude, and $Z = x^{-n}$ then find a and b to

minimize $s_n = \sum (Y_i - aZ_i - b)^2$ in accordance with classical linear regression techniques. b will of course be approximately zero (see figures 1.13 and 1.14). a will be the parameter of interest, and its distribution (for confidence interval determination) is well known.

1.4.2.2.6 It is proposed to compute a and b, as above, for several values of n (see figure 1.15). It is assumed that a minimum will occur (not necessarily at an integer), and this value of a will then be chosen for <u>the</u> model. It is believed that the resulting curve, when convoluted, should yield a P_y (std) similar to the "NLR" or "RAE central" methods, If it does not, the method must be re-examined.

1.4.2.2.7 Thereafter, in examining, say, different ocean areas, navigational environments etc., this ax^{-n} tail will be adjusted to have the proper total area (by changing a only).
There will then presumably remain a small discontinuity at 45 NM. Since convolution involves the tail (above 45 NM) on one hand and the central data (below 45) on the other, this discontinuity will not create a corresponding discontinuity in the convolution. A method for establishing confidence levels for this method will have to be developed.

1.4.2.3 <u>The lateral closing speed ($\dot{y}$)</u>

1.4.2.3.1 During its second meeting, the Group decided to test the data collected from ship-borne radar with regard to a correlation which might exist between the across-track velocity and the across-track deviation of aircraft.

1.4.2.3.2 In this respect a value of across-track velocity was calculated for aircraft on which at least four plotting points were obtained by a ship-borne radar, and the data obtained gave a clear indication of positive correlation between the magnitude of across-track speed and the magnitude of across-track deviation. A comparison has been undertaken of across-track velocity of proximate pairs of aircraft ; the relative across-track velocity was obtained as the difference between the two across-track velocities, thus excluding the component due to convergence or divergence of the respective ATC cleared tracks.

1.4.2.3.3 Since the systematic errors in measuring across-track velocities of single aircraft may not be negligible, the fact that measurements have been taken on pairs of aircraft seen on the same radar has reduced the measurement errors.

1.4.2.3.4 On the basis of the data obtained and represented in Figures 1.16 and 1.17 it appeared reasonable to the Group to adopt an average of 60 Kts (and 7.5 Kts standard error) for the lateral closing speed in the across-track direction for pairs of aircraft having lost their separation, when assessing a 90 NM separation.

1.4.2.4 <u>The longitudinal closing speed (ΔV)</u>

1.4.2.4.1 ΔV is defined as the average relative along-track speed of a pair of same direction aircraft colliding nose-to-tail. This is taken to be represented by the relative along-track speed of aircraft reasonably close together.

1.4.2.4.2 A value of 13 knots has been taken from Table 1.18 which is the average for pairs assig ed to the sa e track, same or adjacent flight level, and within 15 minutes flying time. This average value has a negligible standard deviation and so there is no need to represent it by a probability istribution.

1.4.2.5 <u>The occupancy values : E_y (same) and E_y (opp)</u>

1.4.2.5.1 These parameters have replaced the formerly used parameters called proximity values T_y (same) and T_y (opp). They are defined as the average number of same/opposite direction aircraft occupying segments of length $2S_x$ of the track adjacent to that of the typical aircraft, on the same flight level.

1.4.2.5.2 E_y (same) and E_y (opp) were represented by the probability distributions shown in figures 1.19 and 1.20, taking the average daily flow as 280 flights, in accordance with traffic forecast for the period 1969-1974. These probability distributions refer to an average value of occupancy to be used for the whole area. Table 1.21 shows how occupancy will vary between different latitudes at 20°W and 40°W.

1.4.2.6 <u>The effective length of the collision slab (Λx)</u>

Λx is intended to represent the length of an average aircraft, adjusted to allow for the special shape of vortices and the fact that only one of a pair of aircraft is at hazard during a vortex penetration. The evidence from results of flight-tests conducted by the United States and Canada did not reveal significant hazards. Further investigation is required before firm conclusions can be reached. The Group agreed to assume that the vortex hazard is negligible. Λx has therefore been taken as λx the effective metallic length of an average aircraft. λx is taken equal to 150 feet as previously agreed by the Group.

1.4.3 <u>Presentation of the NAT SPG-4 method</u>

1.4.3.1 <u>Determination of the collision risk estimates</u>

1.4.3.1.1 The Group noted that there were large differences in the percentages of deviations above 45 NM for the different stations. It concluded from this that a weighted addition of the data from the different stations would underestimate the total collision risk. The Group decided that the correct procedure would be to devide the Ocean into a number of sub-areas. For each sub-area i, values should be determined for $(P_y)_i$, $(E_y)_i$ and H_i. These values should then be substituted into equation (2), thereby giving the value of $(N_{ay})_i$ for each sub-area. The value for N_{ay} for the whole ocean could then be obtained as a weighted average of all values of $(N_{ay})_i$. In the determination of $(P_y)_i$ the tail shape formula ax^{-n} discussed in para 1.4.2.2 will be used, where n is determined from the Kilkee radar data and a with its confidence levels is determined from the assumed number of observations and show the assumed number of deviations above 45 NM in the sub-area.

1.4.3.1.2 The Group noted that it wo ld be difficult to apply this method during the meeting, mainly because of the difficulty of determine the values of $(P_y)_i$. It was found, however, that provisional results could be obtained if P_y(std) was assumed to be constant over the complete ocean, and a correction factor was put in to take account of the underestimate this would cause. This method refered to below as "NAT SPG-4 method", is as follows :

a) Divided the ocean into 25 areas as shown in figure 1.24 ;

b) Assign to each area and for each direction of flight (westbound and eastbound) a number of flying hours, H, during the period considered, proportional to the numbers of flying minutes during the data collection exercise indicated in figures 1.22 and 1.23 ;

c) Assign to each area an occupancy factor E_y as follows :

- West of 30° use numbers computed by RAE for 40°W ;

- East of 30° use numbers computed by RAE for 20°W ; these numbers are given in Table 1.21.

d) Account for growth of deviation at start of over-ocean flying by the following approximation :

- Westbound : assume no large deviation East of 20°W and full deviations West of 20°W ;

- Eastbound : assume no large deviations West of 50°W and full deviations East of 50°W ;

e) Assign a constant P_y (std) to all areas other than those to which P_y (std) = 0 is assigned as above. This average P_y (std) is to be computed by averaging linearly the total traffic, weighting each radar cover area in accordance with the amount of flying time for which this area is typical, and computing P_y (std) from this single density function for the tail. However since it is clear that this underestimates the resulting P_y (std), the latter was increased by 12 %.

The weighting f ctors are determined by assigning data from the radar cover areas to the chosen rectangular ocean areas according to the scheme shown in Table 1.24. The resulting weights are as follows :

Gander	0,204
Humbolt 1 and Cook Inlet	0,390
Casco	0,168
Kilkee	0,222
Humbolt 2	0,016

1.4.3.1.3 As the validity of the Gander data had not yet been accepted, it was decided that for these preliminary calculations the axis is moved in such a way as to add 5 NM to the absolute value of all deviations exceeding 40 NM, so that the tail area of the Gander data would include all large deviations outside 40 NM instead of those outside 45 NM. This means that the number of large deviations at Gander was increased for this preliminary calculation from 3 to 5. This change is of little consequence for the present calculation.

1.4.3.2 Confidence limits

1.4.3.2.1. For purposes of applying confidence limits to the above calculations, it is realized that the approximations introduced make it not possible to derive exact confidence limits for the result. Since only a "central estimate" (i.e., a single estimate not unlike a maximum likelihood estimate) is available as a result of the convolutions and summations, some confidence interval must be established to comply with the "basic requirements" set forth by the Group (cf. Summary of Discussions of NAT SPG 2 Meeting, page 4-A-7).

1.4.3.2.2. It has already been noted (para. 1.4.2) that the "NLR method" of Monte Carlo yields a result whose mean (50 %) value is close to that of the "RAE Central estimate" which is the best available estimate of a single value of collision risk which can be deduced from the data. A 90 % confidence interval is easily derived from the "NLR method" by reading off the "90 % of samples" from figure 1.25, and it is a not unreasonable assumption that the same confidence level could be applied to the "Central estimate". Finally, it is a reasonable assumption that the confidence intervals on the "RAE central estimate" and on the calculation described in the previous section are very similar.

1.4.3.2.3 The curve obtained by applying the NLR method to the "RAE combined data" shows that the 90 % confidence level is 1.62 times the mean and the 10 % confidence level (which is, of course, much less important) 0.5 times the mean. It was agreed that confidence levels for the present method should be calculated by applying the same ratios. It should be noted that uncertainties introduced in most of the approximations have comparatively negligible effects, since they are much smaller than 62 %, and will be added on a root mean square basis.

1.4.3.3 Results obtained by NAT SPG-4 method

1.4.3.3.1 The results of the NAT SPG-4 method applied to the data available on all operators are shown in figure 1.26. These calculations indicate, for example, a central estimate of 0.62 accidents per 10 million flying hours at a lateral separation of 90 NM and a 90 % confidence that the rate is not greater than 1.01 accidents per 10 million flying hours.

1.4.3.3.2 The results of the same method applied to the data obtained from all aircraft equipped with Doppler with computer are shown in fig. 1.27. These calculations indicate, for example, a central estimate of 0.36 accidents per 10 million flying hours at a lateral separation of 90 NM.

1.4.3.3.3 The data from approximately 3,500 radar observations of the "best" large operators carrying Doppler with computer (indicated by codes "8" and "12" in column 1 of Table 1.4 on page 1-A-10) do not show a significant departure from an exponential distribution in the "tails" out to 60 NM. Roughly, the "body" and "tails" observations can be fitted with exponential distributions having standard deviations of respectively 11 NM and 10 NM. These two distributions have been chosen to delineate the shaded area in Fig. 1.28 on page 1-A-31, using "central" values for all other parameters in the risk equation.

1.4.4 <u>Interpretation of the collision risk estimates</u>

1.4.4.1 From the results of above computation, which are shown in Figure 1.26, it appears improbable that a 90 NM lateral separation standard applied uniformly over the North Atlantic Region would be "safe" as defined in paragraph 1.4.5.1.

1.4.4.2 On the other hand, there are several ways of dividing the traffic which would isolate safer conditions. Specifically :

- navigation north of the great circle between London and New York appears better than navigation south of this circle ;

- westbound navigation appears better than eastbound navigation ;

- navigation by aircraft equipped with Doppler with computer appears better than navigation by aircraft not so equipped (see Figure 1.4) and,

- some operators appear to navigate better than other operators. (See Table 1.4, page 1-A-10).

1.4.4.3 It appears probable that a 90 NM lateral separation standard would be "safe" if applied only to some appropriate subset of traffic.

1.4.5 Criteria for the assessment of a target level of safety

1.4.5.1 The target level of safety

During its second Meeting, the Group agreed that the "target level of safety" from collision for any of the three separation standards over the North Atlantic would be to keep the fatal accident rate in the range from 0.4 to 0.15 per 10 million aircraft flying hours.

1.4.5.2 The risk due to lateral separation

1.4.5.2.1 During its second meeting, the Group decided to retain, as a starting point, a zero share of the total risk to ATC loop error and an equal sharing of the total risk between the three separation standards, although this appeared to be arbitrary.

1.4.5.2.2 The Group noted that other methods of dividing the risk over the three separations were possible, without changing the overall collision risk. If it could, for instance, be shown that the combined risk due to loss of longitudinal and vertical separation was much less than 2/3 of the total acceptable collision risk and if it were decided that these separations will not be reduced below the values for which this has been established, then a larger part of the total acceptable risk might be assigned to the risk of loss of lateral separation.

1.4.5.3 Cost/benefit analysis

1.4.5.3.1 A second basis for choosing a separation standard could be to sum the following costs :

a) the costs arising from collisions,

b) the costs which are associated with delays and deviations incurred when the standard is applied in air traffic control.

A curve relating the sum of these costs to the size of the standard would be useful in providing an economic basis for decision.

1.4.5.3.2 The Group agreed that it was not practicable to use this basis during the present meeting, but that its development should be included in future work by the Group.

1.5 Conclusions

1.5.1 General

1.5.1.1 After careful consideration of both the operational and mathematical/statistical aspects of the question the Group agreed a number of conclusions which can broadly be classified in the following three categories :

- i) those of a general nature ;
- ii) those concerning the application of lateral separation in the NAT Region ;
- iii) those dealing with the operational aspects of navigational accuracy.

1.5.2 Conclusions of a general nature

1.5.2.1 Considering the time, effort and financial means expended for the preparation, conduct and the evaluation of the results of the data collection programme both by the providers and the users, the Group agreed that it could not be expected that exercises of this nature and scope could be repeated at more or less frequent intervals, even though it was recognized that the programme had yielded invaluable information, not only on the question of lateral separation but on the much broader and more general aspect of navigation capabilities by aircraft operating in the NAT Region.

1.5.2.2 It was however also agreed that, based on the experience gained during the programme both, as regards methods of collection and processing of the data, provider States and users should be encouraged to continue monitoring of navigational accuracy on a reduced scale possibly by arranging for small scale samplings at suitable intervals.

1.5.2.3 With regard to the latter and as far as radar sampling by provider States was concerned, the Group suggested that the States concerned undertake studies with a view to developing technical and organizational methods best suited for this purpose including the possibility of making the necessary technical provisions a permanent feature of the radar installations concerned. It was further suggested that such methods be presented to the Group for review in order to allow for their standardization to the maximum extent possible in order to ensure capability of presentation and evaluation of the data thus obtained.

1.5.2.4 Finally, the Group expressed its belief that the information obtained during the programme would continue to be of value for further studies on the question of separation and this not only in the NAT Region but on a much more general scale. In addition, it was believed that the programme had demonstrated that mathematical/statistical techniques constituted a valuable tool which could materially assist in the resolution of such problems as that of separation.

1.5.3 Conclusions concerning the application of lateral separation in the NAT Region

1.5.3.1 As regards the question of the lateral separation standard to be applied in the NAT Region in actual operations, the findings recorded in para. 1.4 of this Summary appear to indicate that, based on the mathematical/statistical method used by the Group, the application of 90 NM lateral separation would be feasible to certain types of traffic and in certain parts of the Region, however that it could not yet be considered as being "safe" for general application throughout the Region. It was however noted that, in the mathematical/statistical sense, the standard of 120 NM was largely meeting the "safety" requirements used in the mathematical method upon which the work of the Group was based.

1.5.3.2 The Group believed that a subdivision of the Region or the air traffic so that 2 different sets of separation standards could be applied was desirable. However, pending further study of specific techniques for applying such standards, it was believed that they might create formidable difficulties.

1.5.3.3 It seems clear that, if and when for example the navigational performance of all operators were brought up to the level shown by several of the best large operators (of which operator "A" in Figure 1.4 on page 1-A-9 is typical) the general application of a 90 NM standard for lateral separation would be feasible.

1.5.4 Conclusions dealing with the operational aspects of navigational accuracy

1.5.4.1 Since it is obvious that, in any system, overall improvement should not be related to developments in one specialized field only, the Group agreed that, apart from the developments concerning aircraft navigation equipment (see para. 1.5.3.3), it would also be essential to start improvements as of now regarding those specific points of the operational aspects where the review had revealed that certain short-comings existed. While these are described in more details in para. 1.3 of the summary, the Group believed it advisable to summarize them again hereunder with the intention that they would thus receive particular attention by all parties concerned.

1.5.4.2 With regard to the question of amending Annex 6 in order to make it more specific as regards the relation between aircraft equipment carried and the requirements imposed by air traffic control needs (see para. 1.3.24) the Group hoped that States and operators would present studies on this subject as a matter of urgency with a view to reaching agreement at a suitable forum within ICAO. It was further hoped that States and operators would, in the meantime, review their requirements for aircraft navigation equipment for those aircraft used for operations in the NAT Region with a view to ensuring a uniformly high degree of navigational accuracy on such operations.

1.5.4.3 In view of the demonstrated close relationship between navigational accuracy and the degree of sophistication of navigation equipment provided on board the aircraft concerned, when combined with adequate operating techniques, (see para. 1.3.25) the Group hoped that re-equipment programmes for aircraft, and appropriate training and techniques would be rigorously pursued by operators.

1.5.4.4 As regards the operation of land-based radio navigation aids in the NAT Region, and more especially the operation of Loran A chains, the Group hoped that States concerned would make every effort to maintain or bring them into full operational use (See para. 1.3.26 and the Summary of Agenda Item 2).

1.5.4.5 With respect to track keeping accuracy by aircraft operating in the NAT Region and the establishment of a checking procedure in case of deviations from track in excess of more than 20 NM, (see para. 1.3.27) the Group hoped that operators and States concerned would institute the required measures with the least possible delay.

1.5.4.6 As regards the necessity to impress upon flight crews the need to maintain their assigned track as closely as possible and to develop procedures ensuring continued compliance with this requirement (see para. 1.3.29) the Group hoped that States and operators concerned would take appropriate action at their earliest convenience.

1.5.4.7 As to the requirement for flight crews to take confirmative action regarding track keeping at intervals normally not exceeding 20 minutes (see para. 1.3.31) the Group hoped that necessary action to implement this would be taken by all concerned as soon as conditions permitted.

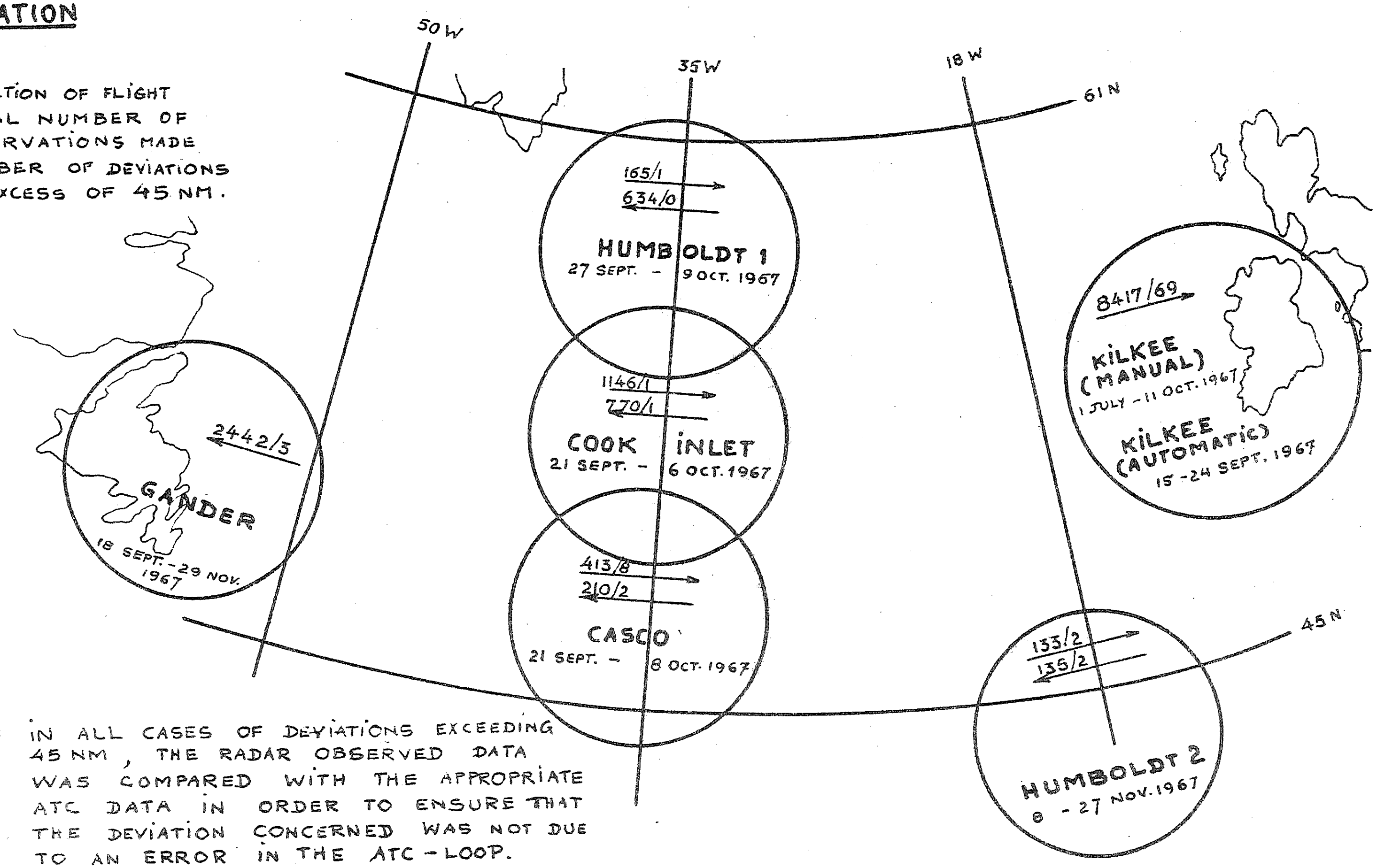
1.5.4.8 With respect to the problems raised by the en-route training of flight crew members (see para. 1.3.32) the Group requested that this matter be given earliest attention by all concerned in order to avoid recurrence of incidents of the nature observed during the data collection programme.

1.5.5 Summary

1.5.5.1 Despite the numerous problems which still require solution or improvement before a reduced lateral separation can safely be introduced in the NAT Region, it became nevertheless apparent that considerable progress in navigation accuracy has been achieved over the years and the Group is therefore confident that, with further progress achieved by the continued demonstration of cooperation and goodwill of all parties concerned, providers and users, it will be possible to reach agreement on mutually satisfactory solutions to this and other questions concerning separation in the NAT Region.

FIGURE 1.1

APPROXIMATE AREA OF COVER OF RADARS USED AT THE DATA COLLECTION EXERCISE AND OTHER APPROPRIATE DATA.



EXPLANATION

① → 165/1 (② / ③)

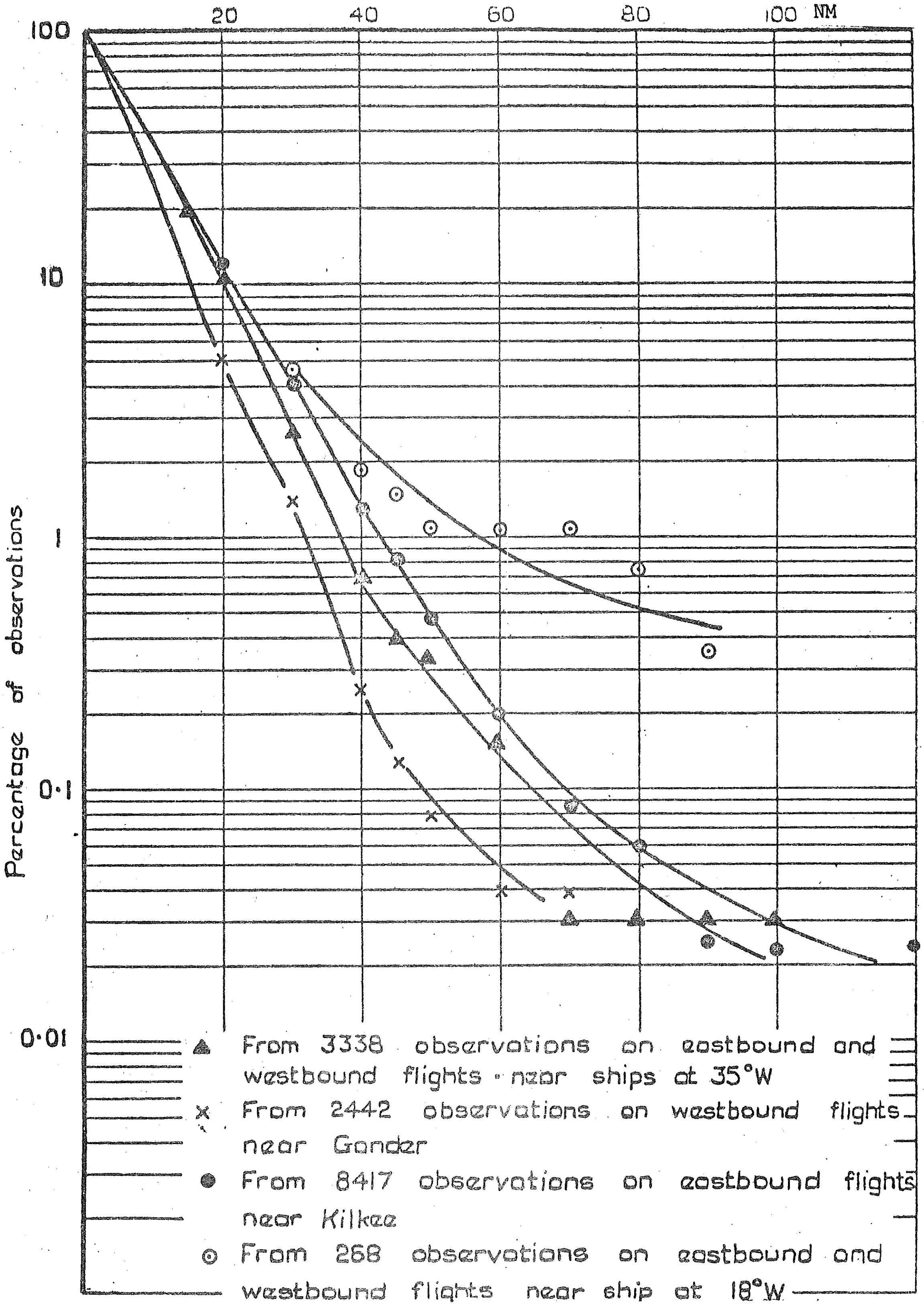
① = DIRECTION OF FLIGHT
② = TOTAL NUMBER OF OBSERVATIONS MADE
③ = NUMBER OF DEVIATIONS IN EXCESS OF 45 NM.

NOTE: IN ALL CASES OF DEVIATIONS EXCEEDING 45 NM, THE RADAR OBSERVED DATA WAS COMPARED WITH THE APPROPRIATE ATC DATA IN ORDER TO ENSURE THAT THE DEVIATION CONCERNED WAS NOT DUE TO AN ERROR IN THE ATC-LOOP.

FIGURE 1.2

Summary presentation of all radar-observed deviations

DEVIATIONS EQUAL TO OR GREATER THAN :



Note : It should be noted that the respective mathematical/statistical weight attributed to the deviations shown in this figure is given in part 1.4 of the summary on this item and that consequently this figure does not take account of this aspect of the problem.

FIGURE 1.3

Distribution of deviations from track measured by ship's radars near longitude 35°W

	Deviation (NM)	58°N/35°W E	58°N/35°W W	53°N/35°W E	53°N/35°W W	48°N/35°W E	48°N/35°W W	Total E	Total W	Total E + W	Case reference number
		LOCATION OF RADAR AND DIRECTION OF FLIGHT									
DEVIATIONS SOUTH OF TRACK (in NM)	100 - 105					1		1		1	1
	⋮										
	60 - 65					4		4		4	2,3,4,5
	55 - 60			1			1	1	1	2	6,7
	50 - 55					1		1		1	8
	45 - 50	1				1		2		2	9,10
	40 - 45	1				2	1	3	1	4	
	35 - 40	3	1	5	1	4	2	12	4	16	
	30 - 35	0	3	9	2	10	3	19	8	27	
	25 - 30	3	9	20	8	17	3	40	20	60	
	20 - 25	9	19	42	30	25	12	76	61	137	
	15 - 20	19	49	79	63	41	15	139	127	266	
	10 - 15	25	84	140	127	48	23	213	234	447	
	5 - 10	55	145	202	161	69	30	326	336	662	
	0 - 5	63	157	225	162	64	35	352	354	706	
DEVIATIONS NORTH OF TRACK (in NM)	0 - 5	41	143	199	122	45	24	285	289	574	
	5 - 10	36	87	160	65	31	26	227	178	405	
	10 - 15	14	36	55	26	22	16	91	78	169	
	15 - 20	5	17	33	12	6	9	44	38	82	
	20 - 25	5	2	24	10	9	6	38	18	56	
	25 - 30	3	1	11	6	7	2	21	9	30	
	30 - 35		2	8	1	2	1	10	4	14	
	35 - 40			2	1	3		5	1	6	
	40 - 45			2	2			2	2	4	
	45 - 50					1		1		1	11
	50 - 55						1		1	1	12
	55 - 60				1				1	1	13
	⋮										
	85 - 90										

The information obtained from operators on the 13 cases for which a deviation of more than 45NM was observed are contained in the explanatory notes. The figures given in the last column of the above table relate to the case in question.

FIGURE 1.3

Explanatory information on 13 cases of radar observation of more than 45NM at position 35°W

CASE 1 :

Date	: 26 September 1967
Source of Information	: Casco
Type of aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 102.7 NM South
Equipment used	: No Doppler, Loran A fixing used. Celestial heading checks. Consol, Radio Altimater
Comment	: Form 1-D stated deviation 33 NM South Reason given ; Poor heading Control.

CASE 2 :

Date	: 27 September 1967
Source of Information	: Casco
Type of aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 63.7 NM South
Equipment used	: No doppler ?
Comment	: Company regretted that documentation was missing and Form 1-D could not be submitted.

CASE 3 :

Date	: 27 September 1967
Source of Information	: Casco
Type of aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 62.2 NM South
Equipment used	: Doppler and computer, Celestial used for heading and fixing checks, Loran A fixing
Comment	: Form 1-D states no deviation over 30 NM.

CASE 4

Date	: 1st October 1967
Source of information	: Casco
Type of aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 64.7 NM South
Equipment used	: No doppler. Loran A and Celestial used for fixing and heading checks
Comment	: Form 1-D states no deviation over 30 NM.

CASE 5 :

Date	: 10 October 1967
Source of information	: Casco
Type of aircraft	: DC 8
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 63.8 NM South
Equipment used	: Doppler Sensor only. Loran A used, Celestial not used
Comment	: Form 1-D states no deviation over 30 NM.

CASE 6 :

Date	: 2nd October 1967
Source of information	: Cook Inlet
Type fo aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 56.8 NM South
Equipment used	: No information
Comment	: A Form 1-D was received but was found to be for another flight. The company wrote to say that this flight experienced a period of navigational difficulty in the vicinity of 33W and that inspection of the nav. chart indicated that the aircraft was probably about 30NM South of track while within range of weather ship "Charlie". They also stated that the deviation would be as high as 65-70 NM.

CASE 7 :

Date	: 2nd October 1967
Source of information	: Casco
Type of aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Westbound
Observed deviation	: 59.1 NM South
Equipment used	: Loran A, Doppler and computer
Comment	: Form 1-D states no deviation over 30 NM.

CASE 8 :

Date	: 26 September 1967
Source of information	: Casco
Type of aircraft	: DC 8
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 53.6 NM South
Equipment used	: No Doppler, Loran A and Celestial used
Comment	: Form 1-D states no deviation over 30 NM.

CASE 9 :

Date	: 7 October 1967
Source of information	: Humboldt
Type of aircraft	: MILITARY 4 JET
Frequent user	: No
Direction of flight	: Eastbound
Observed deviation	: 49.7 NM South
Equipment used	: No information
Comment	: No Form 1-D received. However, operator stated there was a deviation, of the order measured by radar, at that position. The error was due to a mis-plotted celestial fix.

CASE 10 :

Date	: 1st October 1967
Source of information	: Casco
Type of aircraft	: B 707
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 45.5 NM South
Equipment used	: Doppler sensor only. Loran A, Celestial, for fixing and heading
Comment	: Form 1-D states a deviation of 46 NM. Reasons given: i) crew under training ii) Doppler-erroneous reading.

CASE 11 :

Date	: 7 October 1967
Source of information	: Casco
Type of aircraft	: DC 8
Frequent user	: Yes
Direction of flight	: Eastbound
Observed deviation	: 45.3 NM North
Equipment used	: No information
Comment	: Form 1-D not received.

CASE 12 :

Date	: 7 October 1967
Source of information	: Casco
Type of aircraft	: DC 8
Frequent user	: No
Direction of flight	: Westbound
Observed deviation	: 51.2 NM North
Equipment used	: No information
Comment	: Form 1-D not received.

CASE 13 :

Date	: 30 September 1967
Source of information	: Cook Inlet
Type of aircraft	: DC 8
Frequent user	: No
Direction of flight	: Westbound
Observed deviation	: 58 NM North
Equipment used	: Loran A, Celestial for fixing and heading checks
Comment	: Form 1-D stated no deviation over 30 NM. (Flight log reported Ocean Station Vessel "Juliett" off station?)

FIGURE 1.4

Relationship between navigation equipment available on board of aircraft and the navigation accuracy achieved

DEVIATION EQUAL TO OR GREATER THAN :

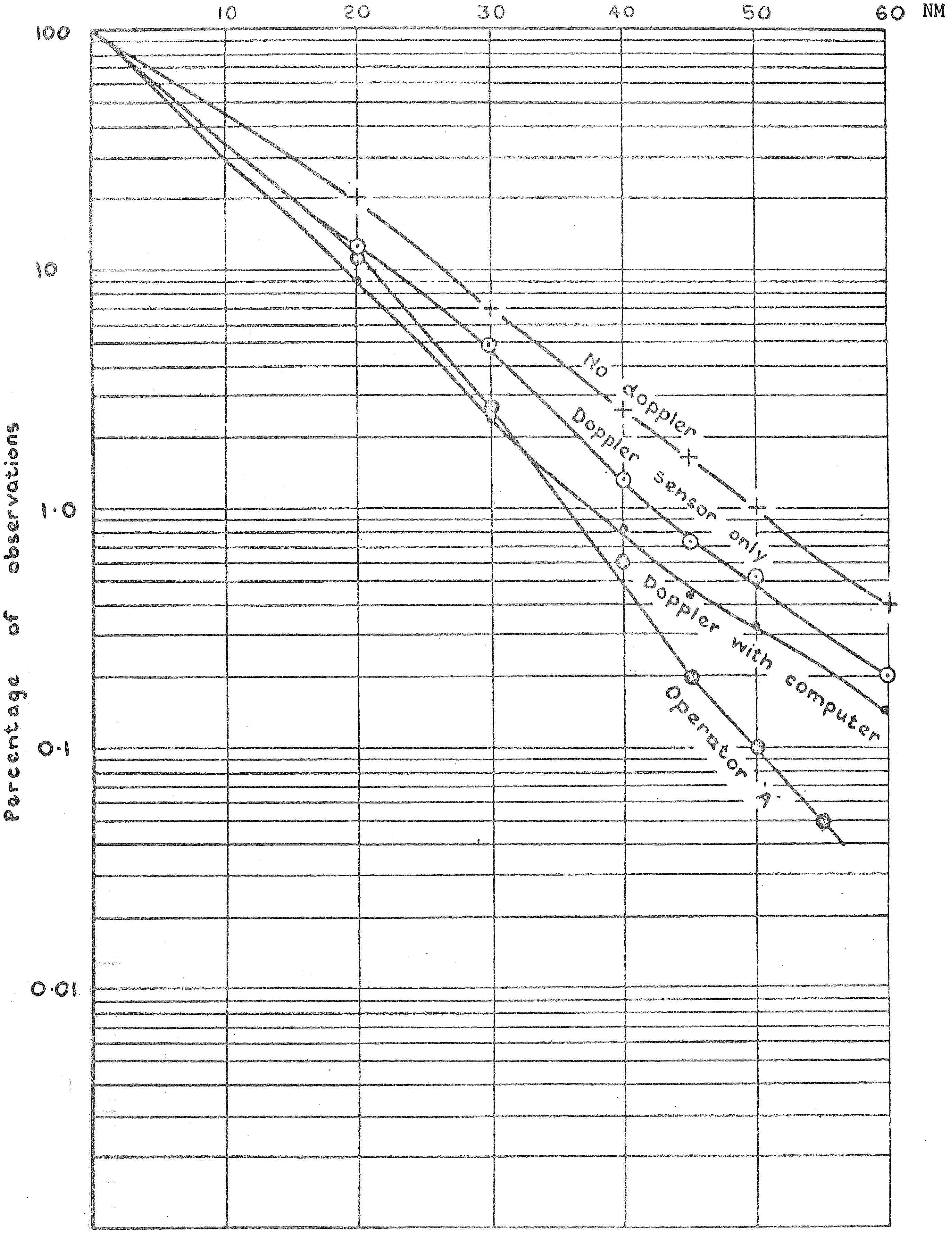


Table 1-4

NAT SPG - NORTH ATLANTIC DATA COLLECTION - 1967/68 - SUMMARY OF SOME RESULTS

OPERATOR PERFORMANCE				OPERATOR EQUIPMENT & TECHNIQUE						SOURCES OF DATA - LARGE DEVIATIONS										
CODE AIRCRAFT TYPE AND OPERATOR	APPROX% OF TOTAL TRAFFIC	TOTAL OF LARGE DEVIATIONS	KILKEE AUTO AND MANUAL SD-& 417 TRANSITS	LORAN 'A'	DOPPLER & COMPUTER	DOPPLER SENSOR ONLY	CELESTIAL	CONSOL	SEPARATE CREW MEMBER FOR NAVIGATION	HUMBOLDT 1		COOK INLET		CASCO		HUMBOLDT 2		GANDER	KILKEE AUTO	KILKEE MANUAL
										E	W	E	W	E	W	E	W	W	E	E
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1*	<½	-	5.17	/	/	•	/	/	/											
2	<½	-	8.19	/	/	•	/	/	/											
3	5	2(2)	10.05	/	/	•	/	/	•											2(2)
4	2½	-	10.06	/	/	•	/	/	/											
5	4	4(4)	10.31	/	/	•	/	/	/											4(4)
6	5	4(2)	10.73	/	/	•	/	/	/											4(2)
7	7	4(3)	11.18	/	/	•	/	/	/											4(3)
8	6	1	11.27	/	/	•	/	/	/											1
9	2½	4(1)	11.31	/	/	•	/	/	/					1(1)						3
10	4½	-	11.35	/	/	•	/	/	/											
11	1	-	12.23	/	/	•	/	/	/											
12	18	11(4)	13.10	/	/	•	/	/	/	1			2	1	1(1)					6(3)
13	8	10(5)	13.53	/	•	/	/	/	/			1		1				1		7(5)
14*	<½	-	13.55	/	/	•	/	/	/											
15	-	-	13.66	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
16	4	4(1)	13.68	/	•	/	/	/	/											4(1)
17	5	7(5)	13.68	/	/	•	/	/	/											7(5)
18	1½	1(1)	14.21	/	•	/	/	/	/											1(1)
19	1	2(2)	14.71	/	/	•	/	•	•											2(2)
20*	<½	-	15.61	/	/	•	•	/	•											
21	-	-	15.63	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
22	2	-	15.65	/	•	/	/	•	/											
23	4½	11(4)	15.67	/	•	/	/	/	/					1(1)				1		9(3)
24	½	1(1)	15.92	—	NO LOGS	RECEIVED	—	—	—						1(1)					
25	1½	3	15.99	/	•	•	/	/	/											3
26	½	1(1)	16.07	/	•	•	/	/	/					1(1)						
27	2	5(2)	16.21	/	•	/	/	/	/					1(1)					1	3(1)
28*	<½	-	17.04	/	•	/	/	/	/											
29	<½	3(2)	17.08	•	/	•	•	•	/							1(1)	1(1)			1
30	13	40(28)	17.23	/	•	•	/	/	/			2(1)		3(3)				1(1)	7(5)	27(18)
31	½	2(1)	17.49	/	•	•	/	/	/				1(1)							1
32*	<½	1(1)	17.70	/	•	/	/	/	/	1(1)										
33*	<½	-	18.91	/	•	/	/	/	/											
34	1	3(3)	19.76	/	•	/	/	/	/										1(1)	2(2)
35	<½	5(4)	21.58	/	/	•	/	/	/											6(5)
36	½	2(2)	23.03	—	NO LOGS	RECEIVED	—	—	—											2(2)
37	<½	6(5)	24.92	•	/	•	/	/	/									1(1)		4(3)
38*	<½	1(1)	27.66	/	/	•	/	/	/											1(1)
39	½	4(4)	-	—	—	—	—	—	—					1(1)		1(1)	1(1)	1(1)		

NOTES :-

1. Coded designations recorded in Col. 1 are related both to specific aircraft fleets of individual operators and to total operator product ; the latter case applying to code Nos 5, 15, 21, 27, which summarise the Standard Deviations (SD) of more than one type operated by the same operator.
2. An asterisk (*) in Col. 1 indicates that this operator carried out less than 15 flights from which data could be obtained.
3. In Cols 4 and 11 - 22, large deviations of more than 40NM are indicated by numbers. The number in brackets, i.e. (3) indicates the number of occasions on which the deviation exceeded 45NM.
4. The percentage values shown in Col. 2 and the total of large deviations in Col. 3 relate to the total group of aircraft participating in the data collection programme. Values in Col. 4 relate only to Kilkee data as indicated.

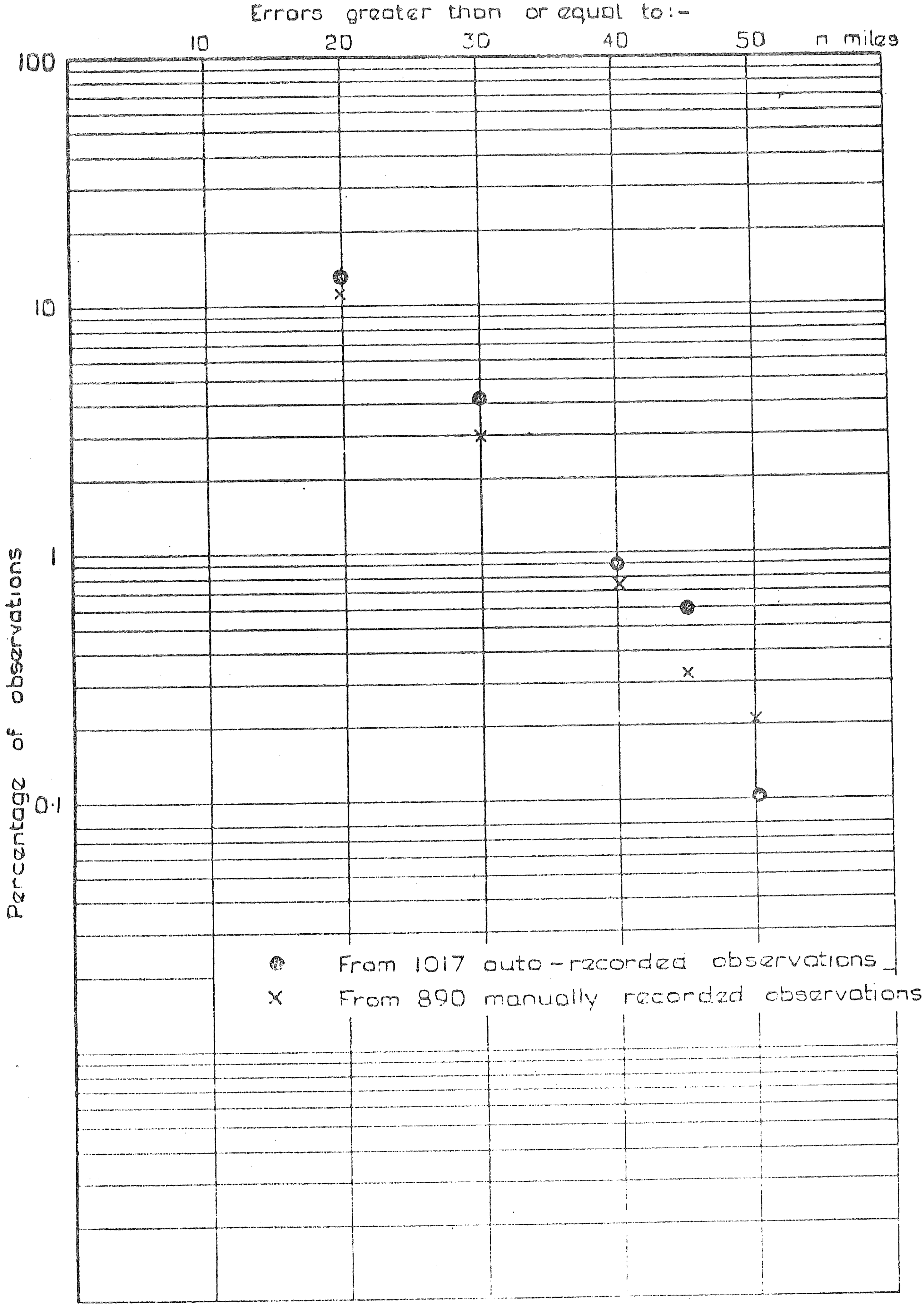


Fig. 1.5 Comparison of manual with auto-recorded observations at Kilkee (Sept 15—25)

Table 1.6 a)

Differences between estimates of across-track errors obtained by two overlapping ships' radars

Size of Difference (nm)	Number
0-5	243
5-10	68
10-15	8
15-20	4
20-25	2
TOTAL	325

Table 1.6 b)

Differences between estimates of across-track velocities obtained by two overlapping ships' radars

Difference* (knots)	Positions of Ships				
	48N/35W and 53N/35W		53N/35W and 58N/35W		TOTAL
	East	West	East	West	
-100 to -91		1		1	2
- 90 to -81		0	1	0	1
- 80 to -71		0	0	0	0
- 70 to -61		0	0	1	1
- 60 to -51		0	1	1	2
- 50 to -41		3	4	2	9
- 40 to -31	1	1	5	4	11
- 30 to -21	0	5	6	6	17
- 20 to -11	1	1	4	13	19
- 10 to - 1	2	1	17	21	41
0 to 9	4	1	14	15	34
10 to 19	3	1	14	14	32
20 to 29	4	0	15	6	25
30 to 39	3	1	3	5	12
40 to 49	3		4	6	13
50 to 59	2		1	1	4
60 to 69	1		0	1	2
70 to 79			1	1	2
80 to 89			0		0
90 to 99			1		1
100 to 109			1		1
110 to 119			1		1
TOTAL	24	15	93	98	230
Mean (kts)	+21	-24	+6	+2	

* The sign convention is that the across-track velocity (positive if Northbound, negative if Southbound) estimated from the more Southerly ship is subtracted from the estimate obtained from the more Northerly ship.

EFFECT OF INCLINATION OF TRACKS

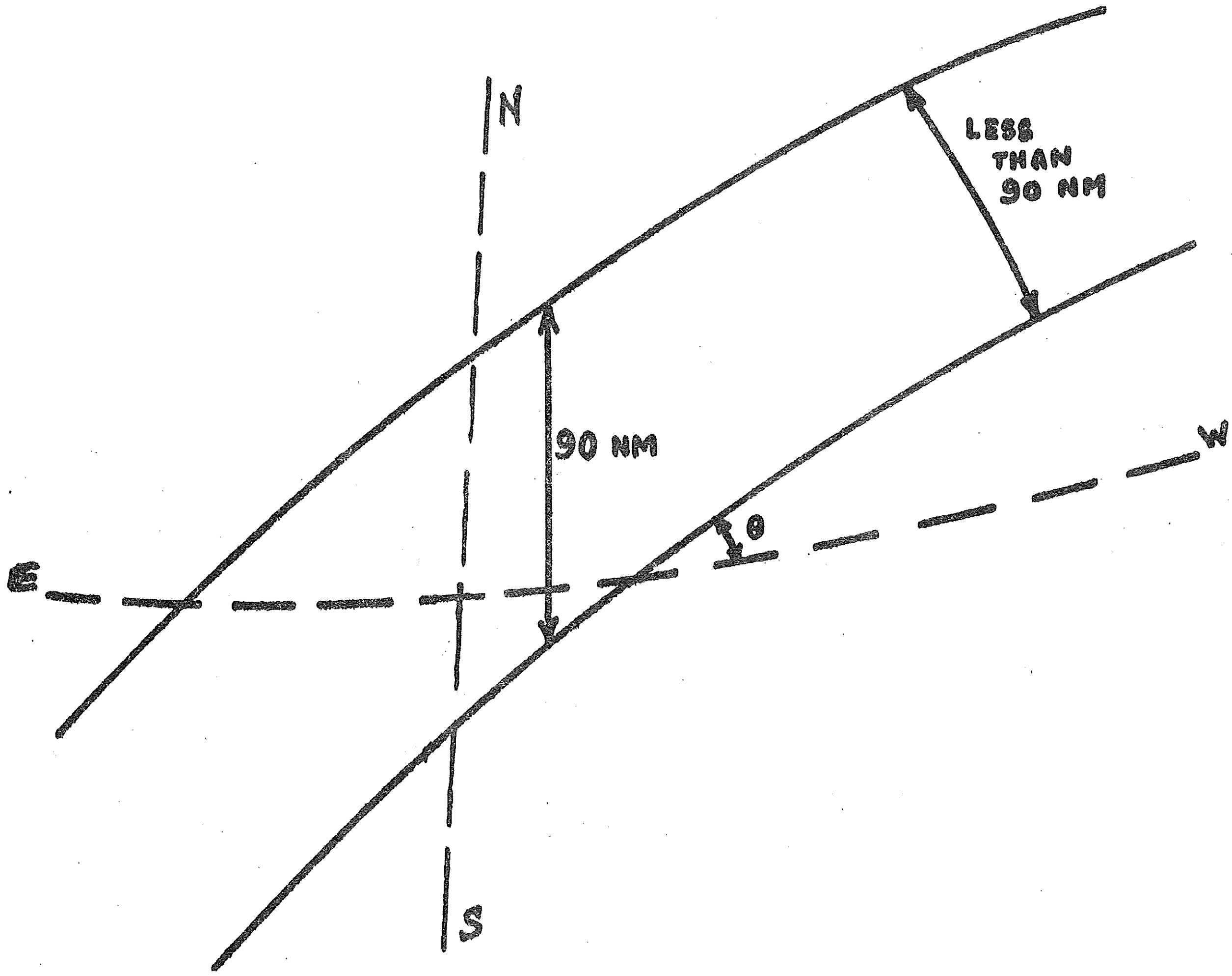


Fig. 1.7

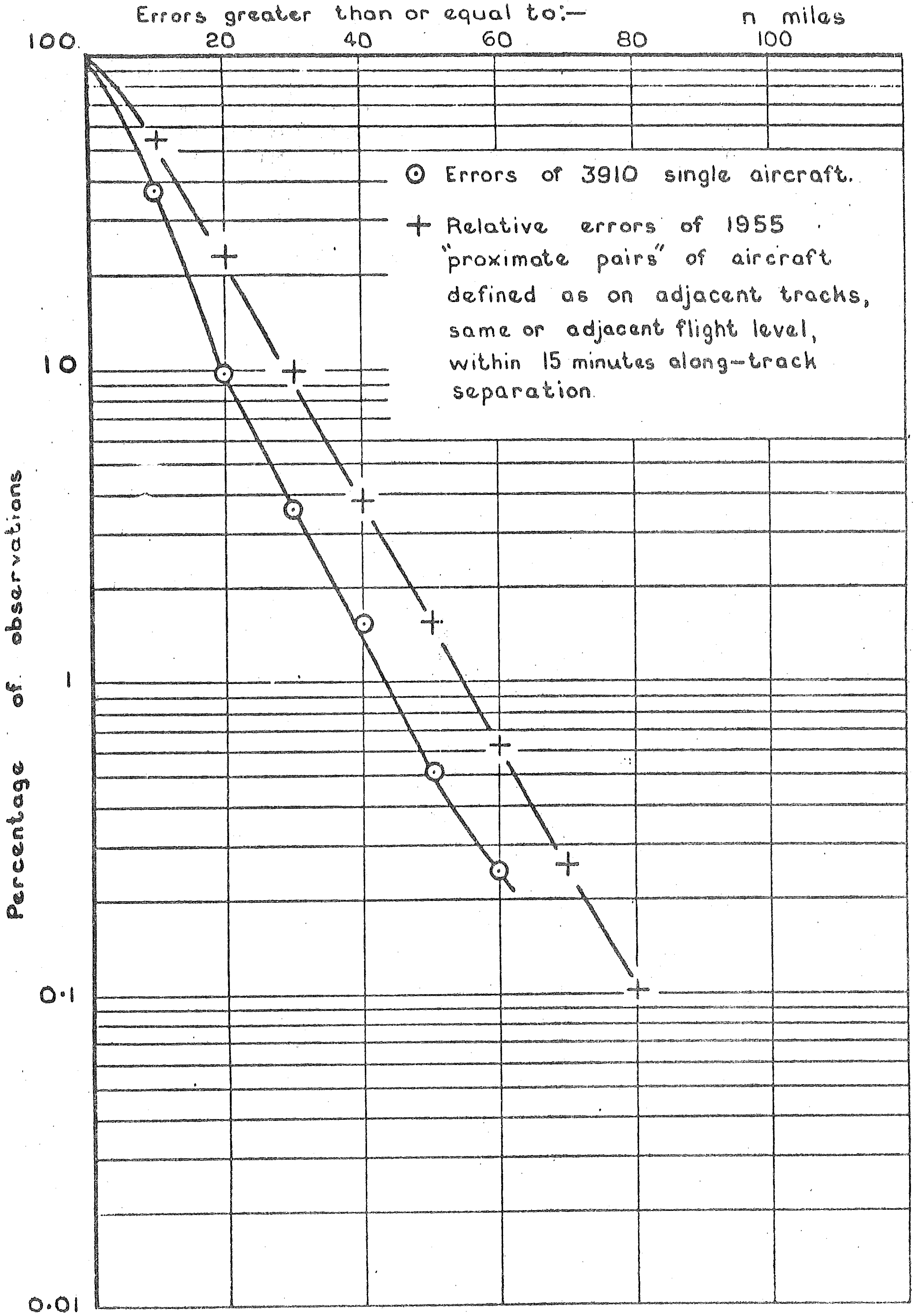


Fig 1.8 Track-keeping errors of pairs of aircraft recorded manually at Kilkee

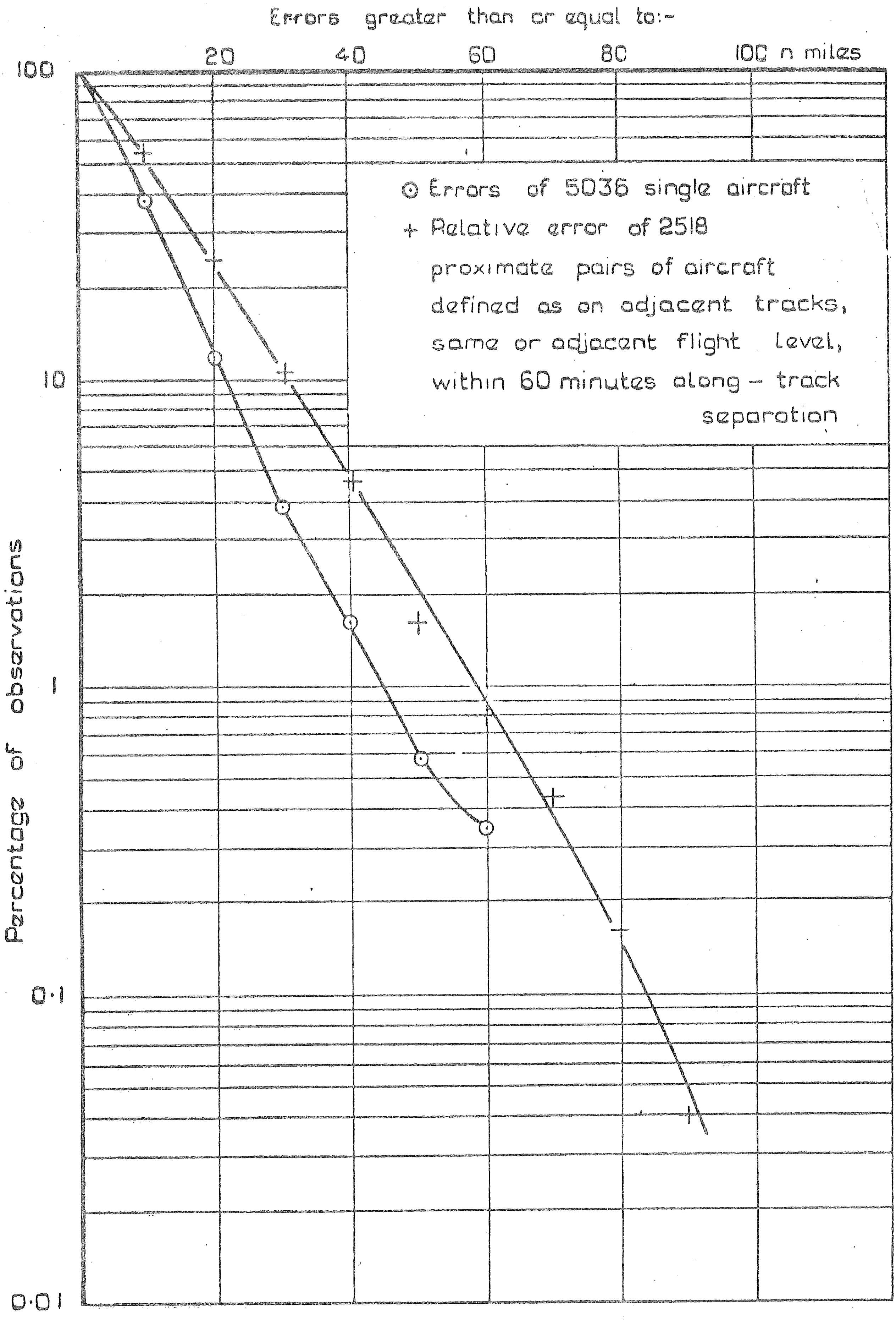


Fig. 1.9 Track-keeping errors of pairs of aircraft recorded manually at Kilkee

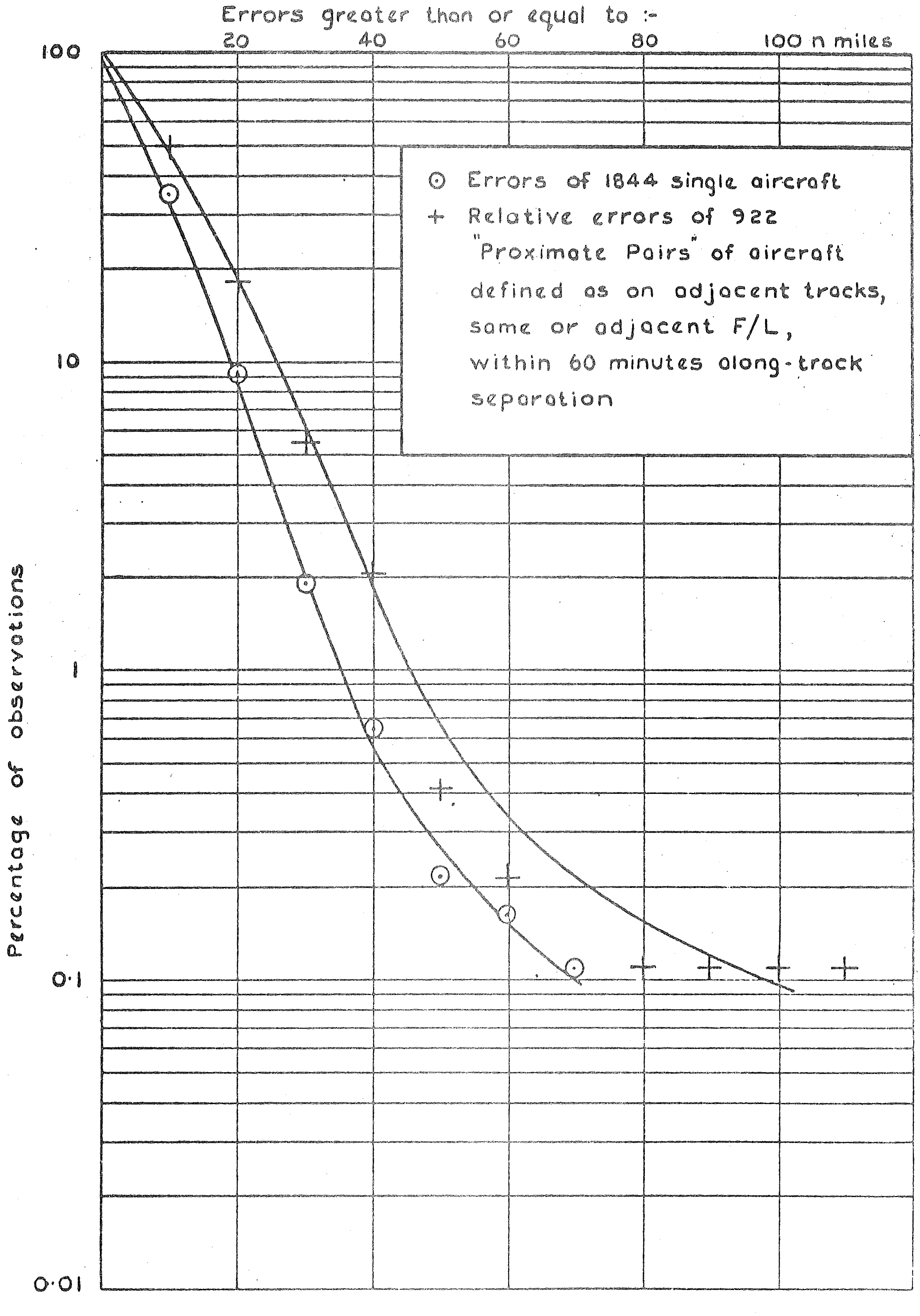


Fig. 1.10 Track-keeping errors of pairs of aircraft recorded by ships

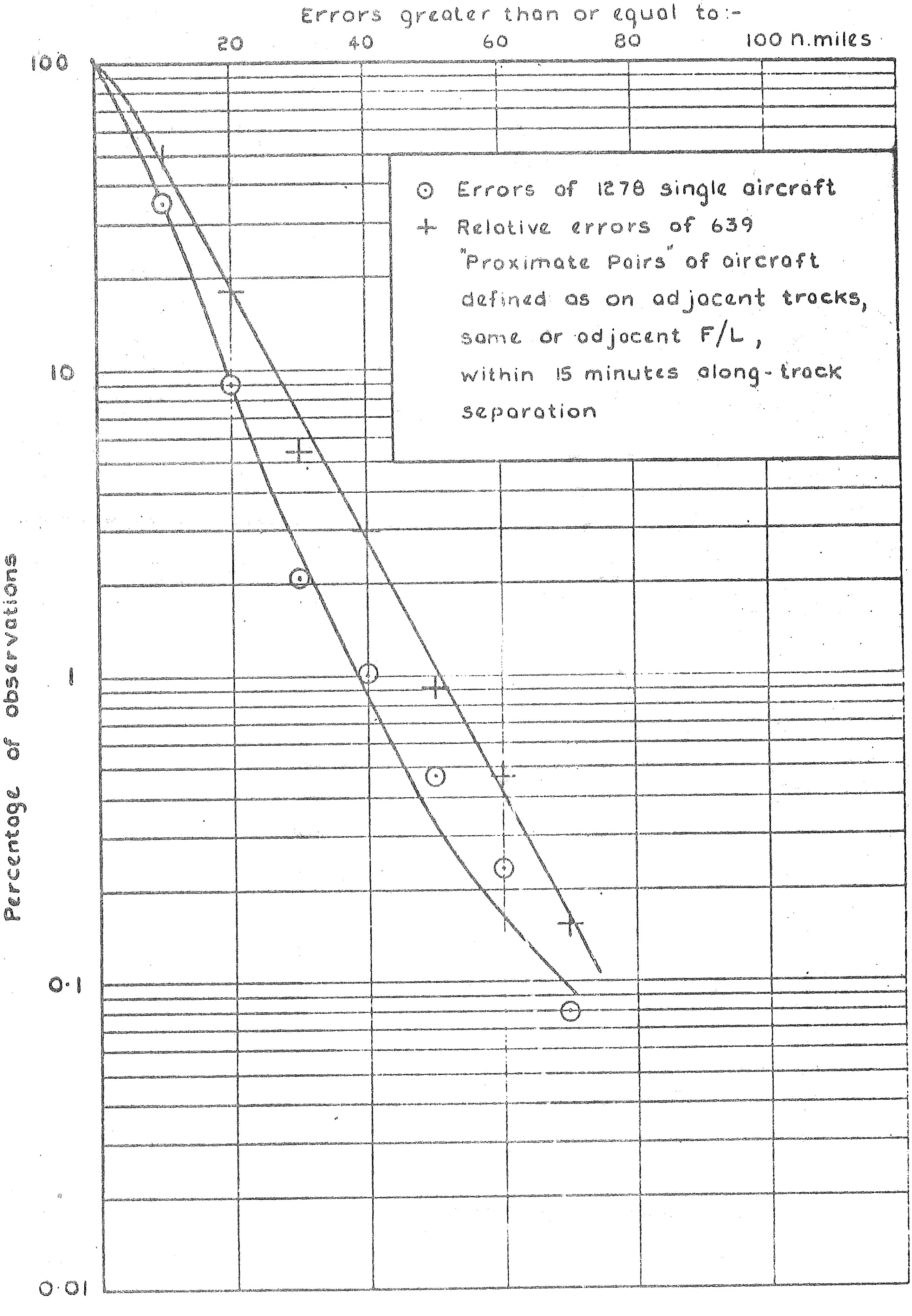


Fig. 1.11 Track-keeping errors of pairs of aircraft recorded by ships

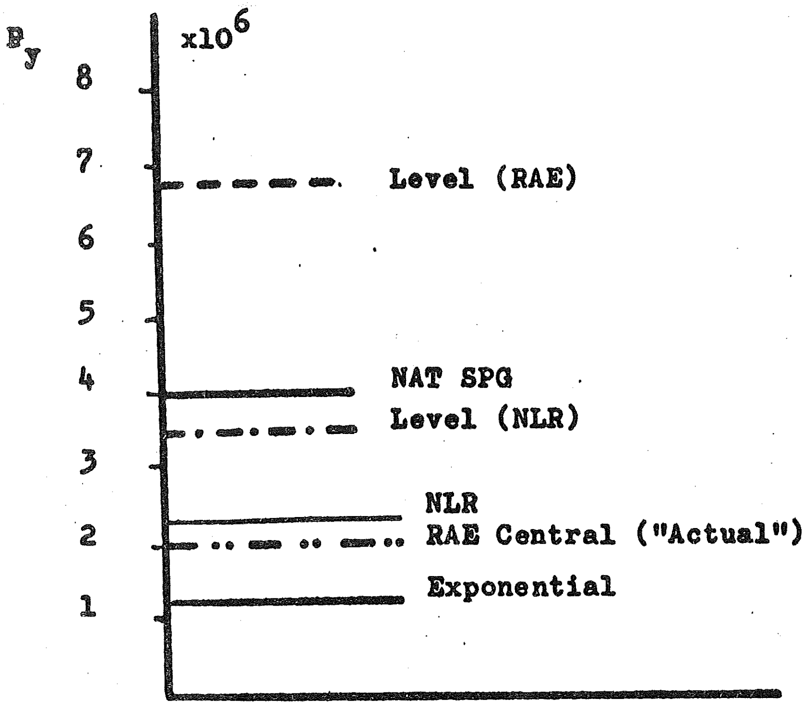


Fig. 1.12 Effect of various tail-shape assumptions

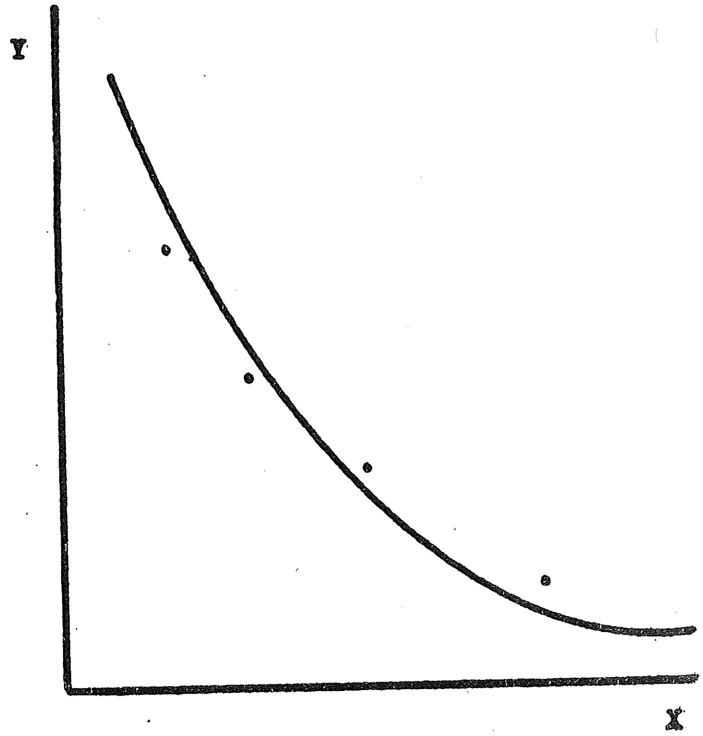


Fig. 1.13

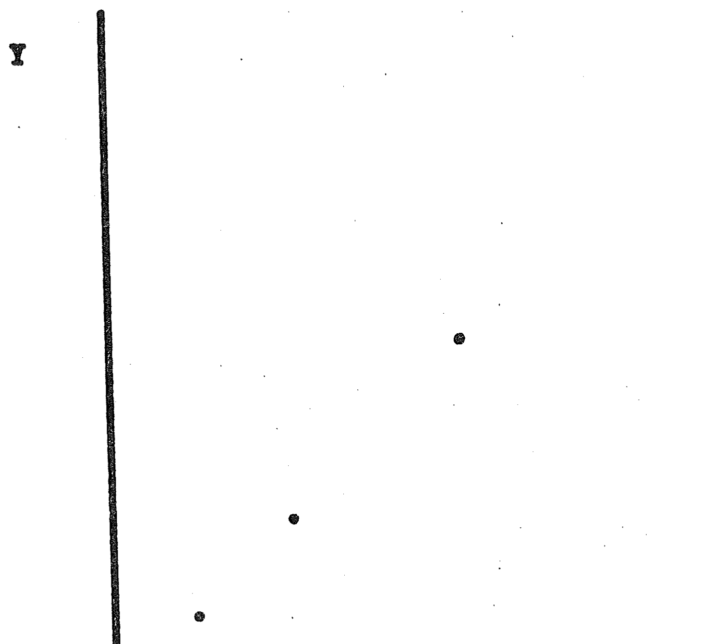


Fig. 1.14

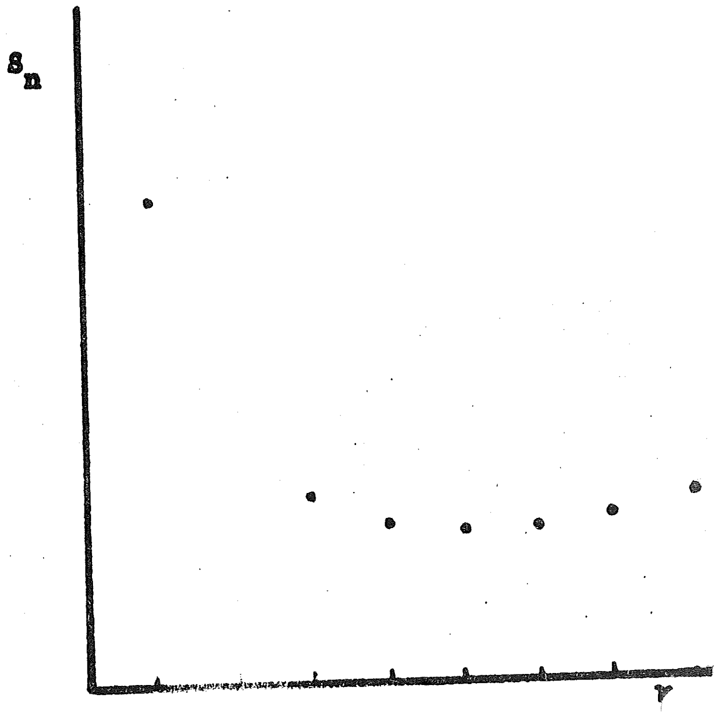


Fig. 1.15 $S_n = \sum (Y_i - aZ_i - b)^2$

Criteria for proximate pairs: Assigned to adjacent tracks, to same or adjacent flight level, and within 60 minutes along-track separation.

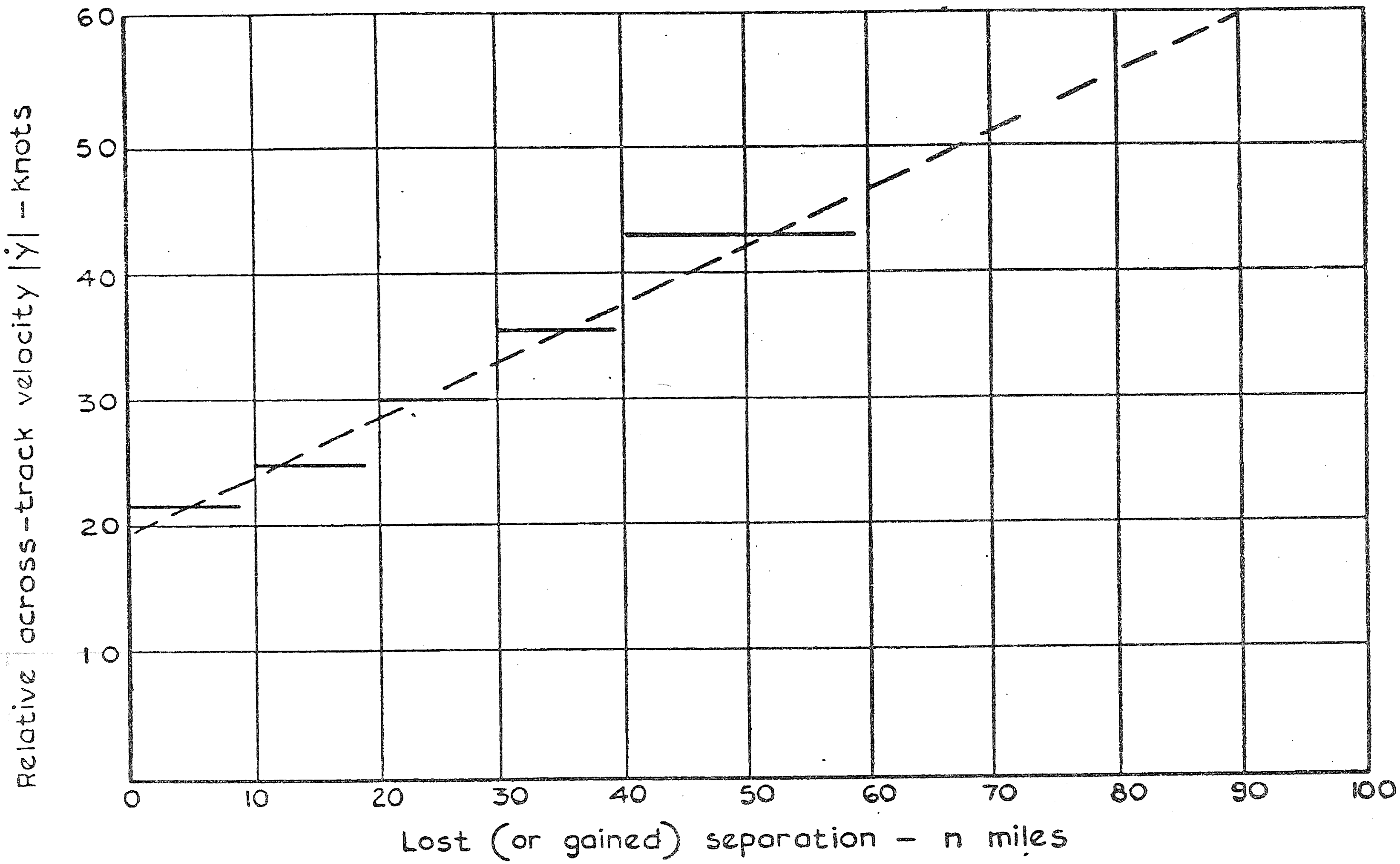


Fig. 1.16 Mean values of $|\dot{y}|$ for different bands of $|\overset{*}{y}|$

Criteria for proximate pairs: Assigned to adjacent tracks, to same or adjacent flight level, and within 15 minutes along-track separation

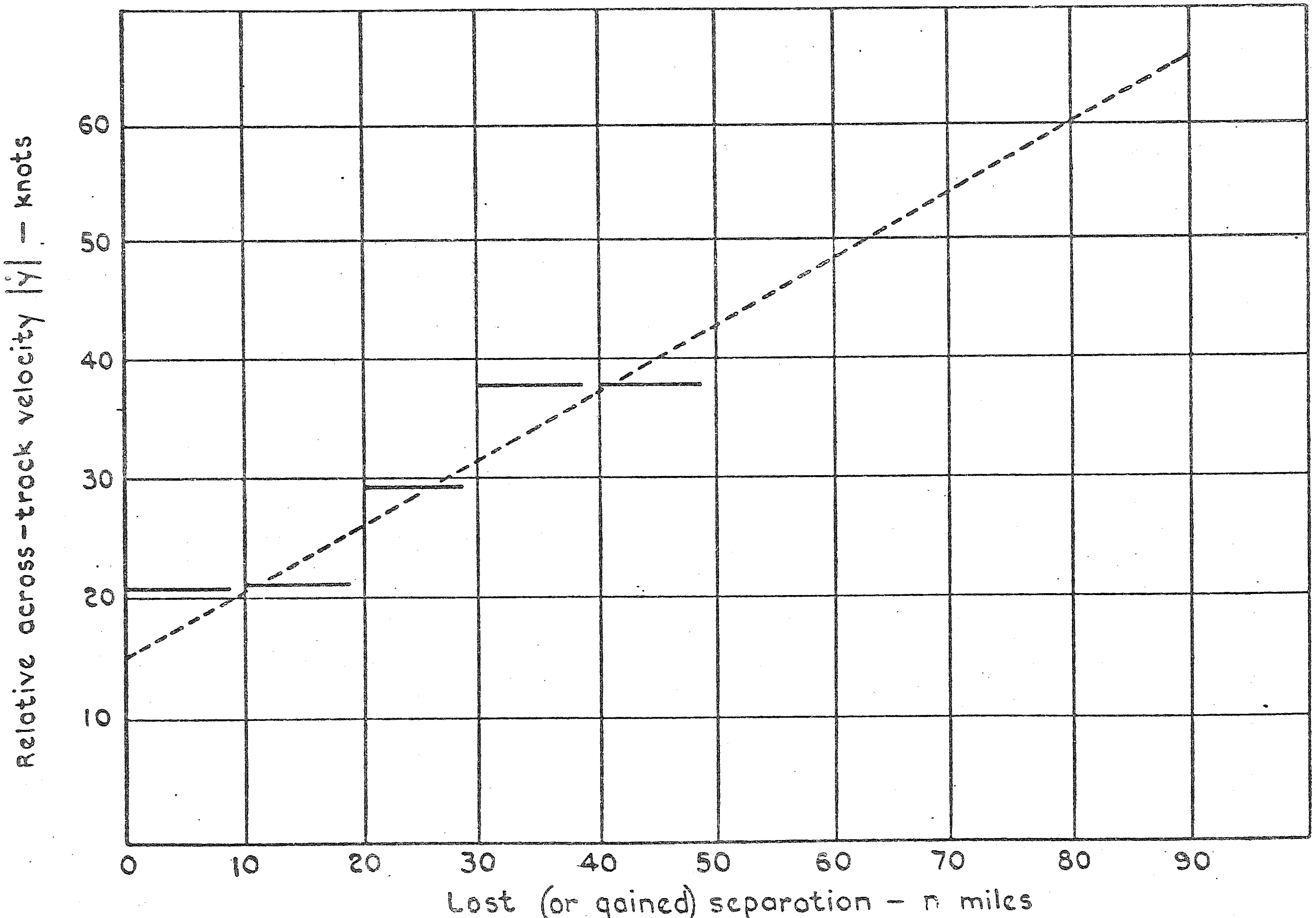


Fig. 1.17 Mean values of $|\dot{y}|$ for different bands of $|y|$

Table 1.18: Distributions of relative along-track speeds of proximate pairs of aircraft.

Relative along-track speed (knots)	Criteria: assigned to the same track at the same or adjacent flight levels and within ...	
	... 15 minutes	... 60 minutes
0 - 4	109	180
5 - 9	88	194
10 - 14	76	151
15 - 19	52	102
20 - 24	34	53
25 - 29	25	43
30 - 34	9	34
35 - 39	6	19
40 - 44	8	10
45 - 49	1	6
50 - 54	3	7
55 - 59	1	2
60 - 64	2	2
65 - 69	1	2
70 - 74	3	4
75 - 79	2	1
80 - 84		
85 - 89		2
90 - 94		1
95 - 99		1
over 100	2	6
mean (excluding values over 100 knots)	13.2	14.2

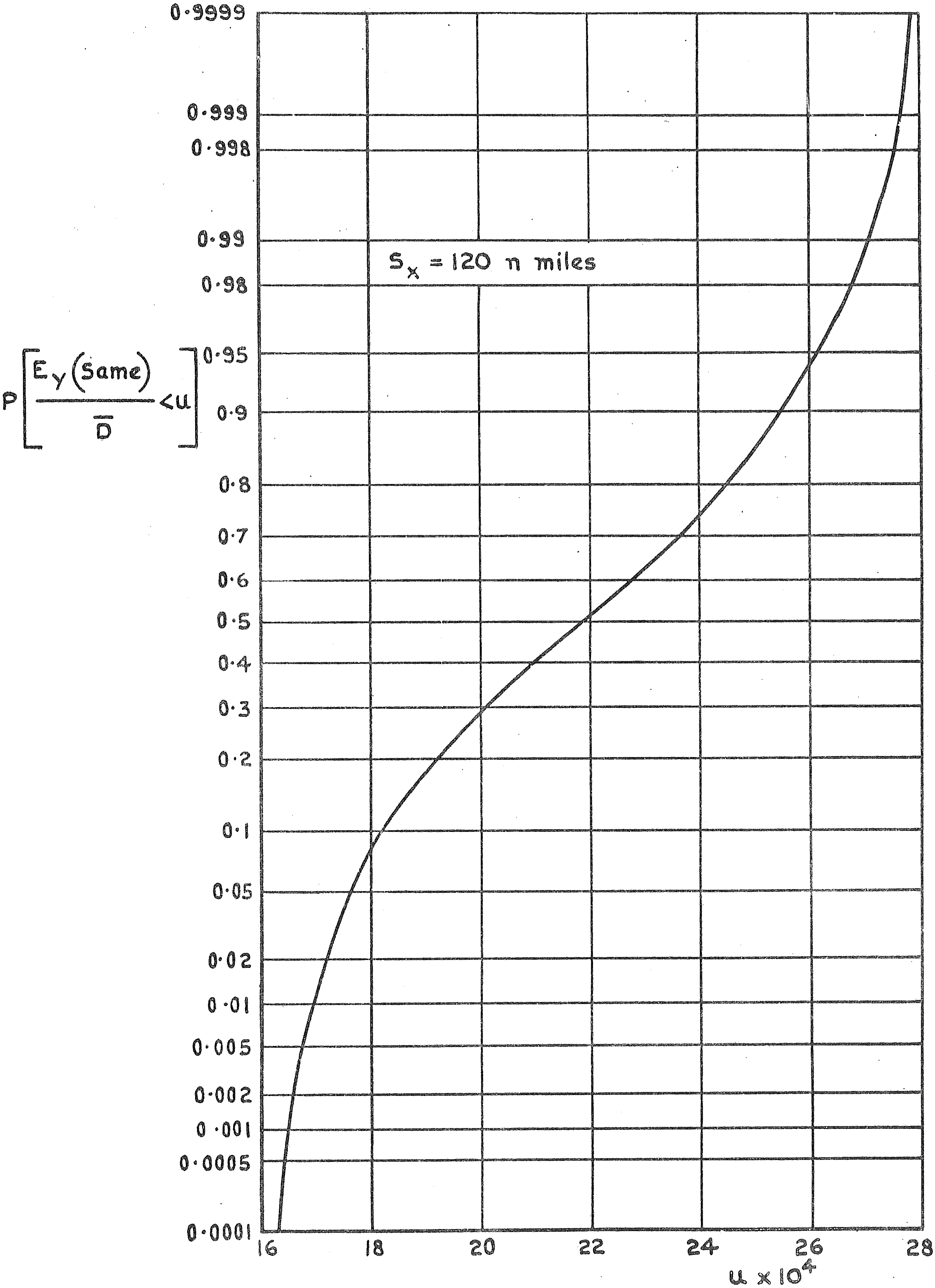


Fig. 1.19 Distribution function assigned to same-direction lateral occupancy

($\overline{D}$ = forecast average daily number of flights in period considered)

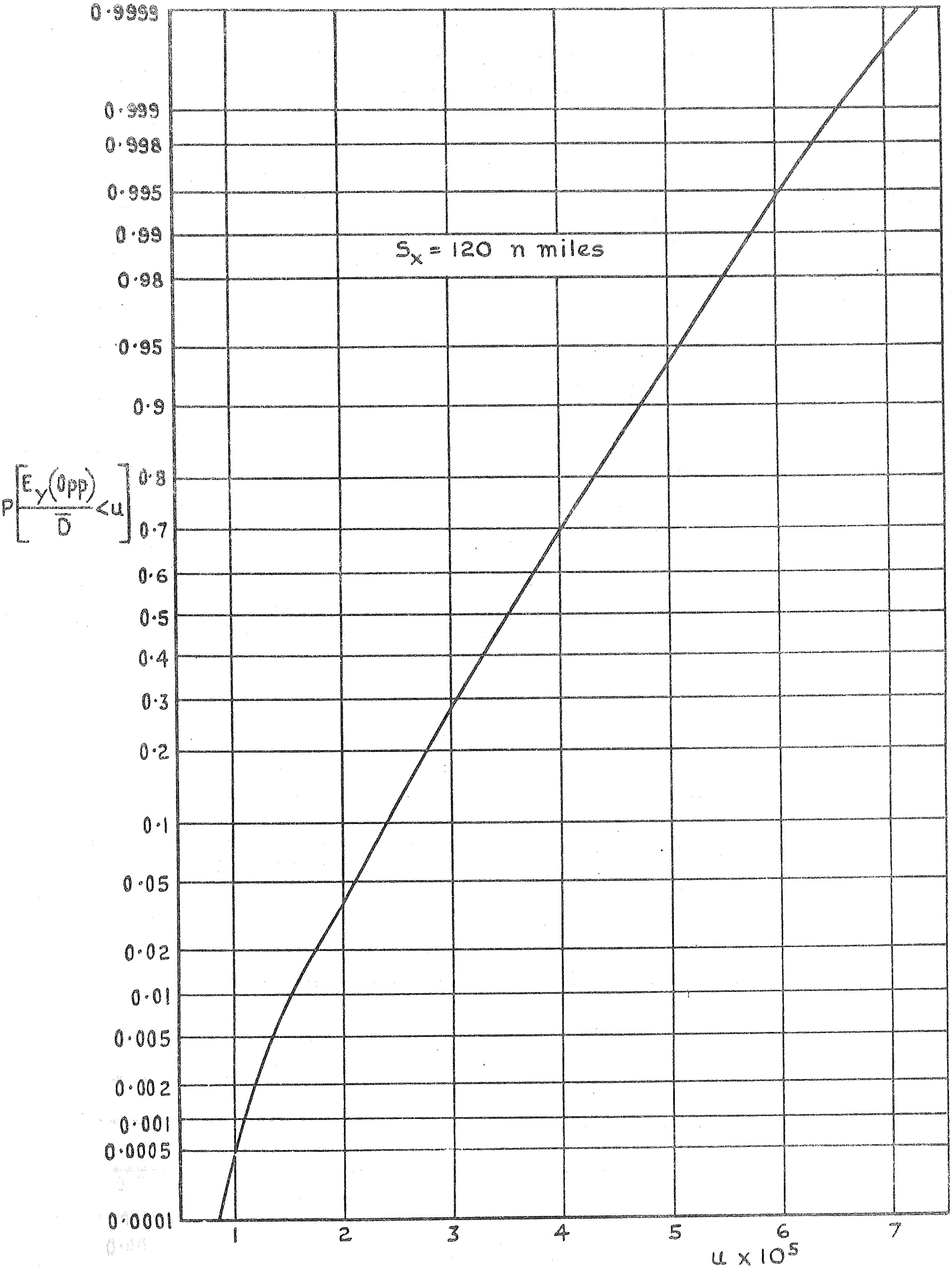


Fig. 1.20 Distribution function assigned to opposite – direction lateral occupancy
($\overline{D}$ = forecast average daily number of flights in period considered)

Fig. 1.21

SUBDIVISION OF THE NAT AREA FOR ASSIGNMENT OF OCCUPANCIES

EASTBOUND AND WESTBOUND

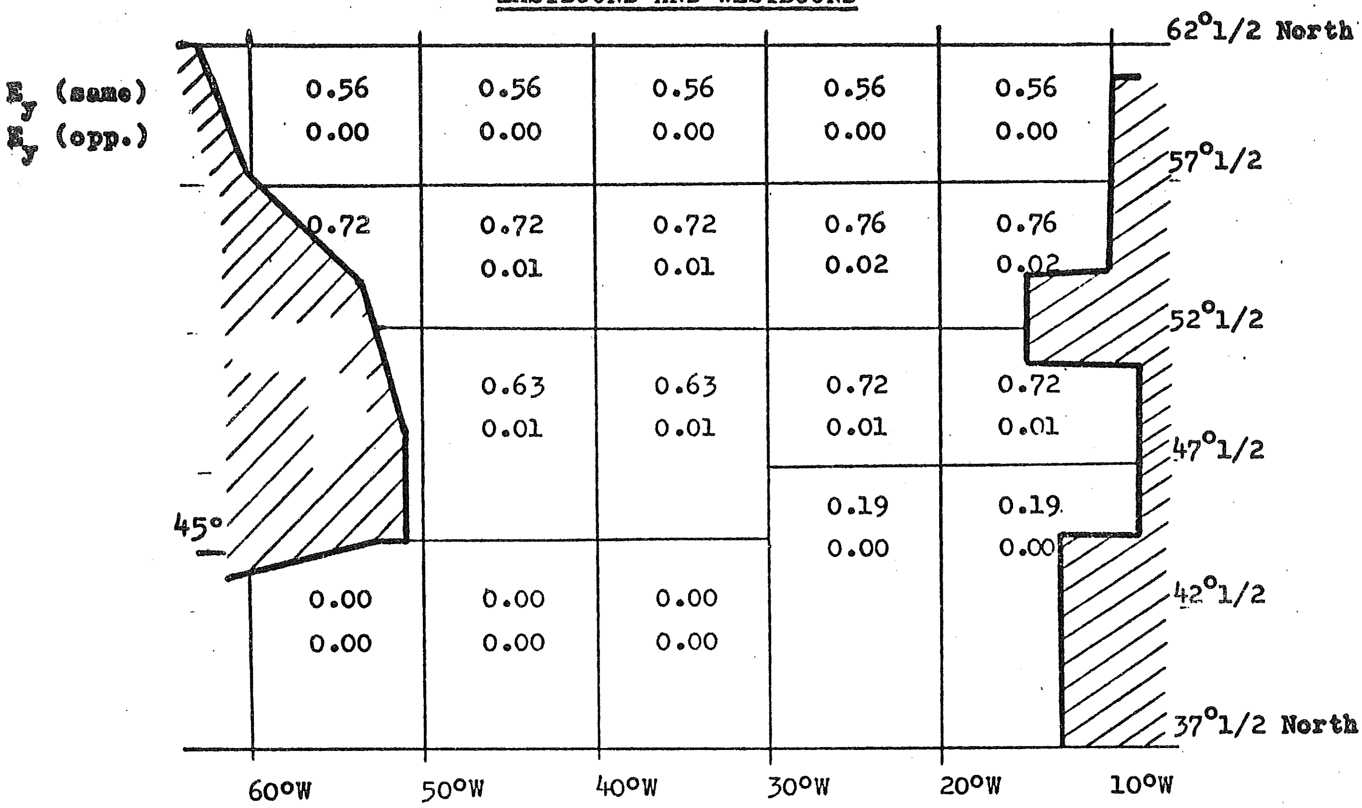
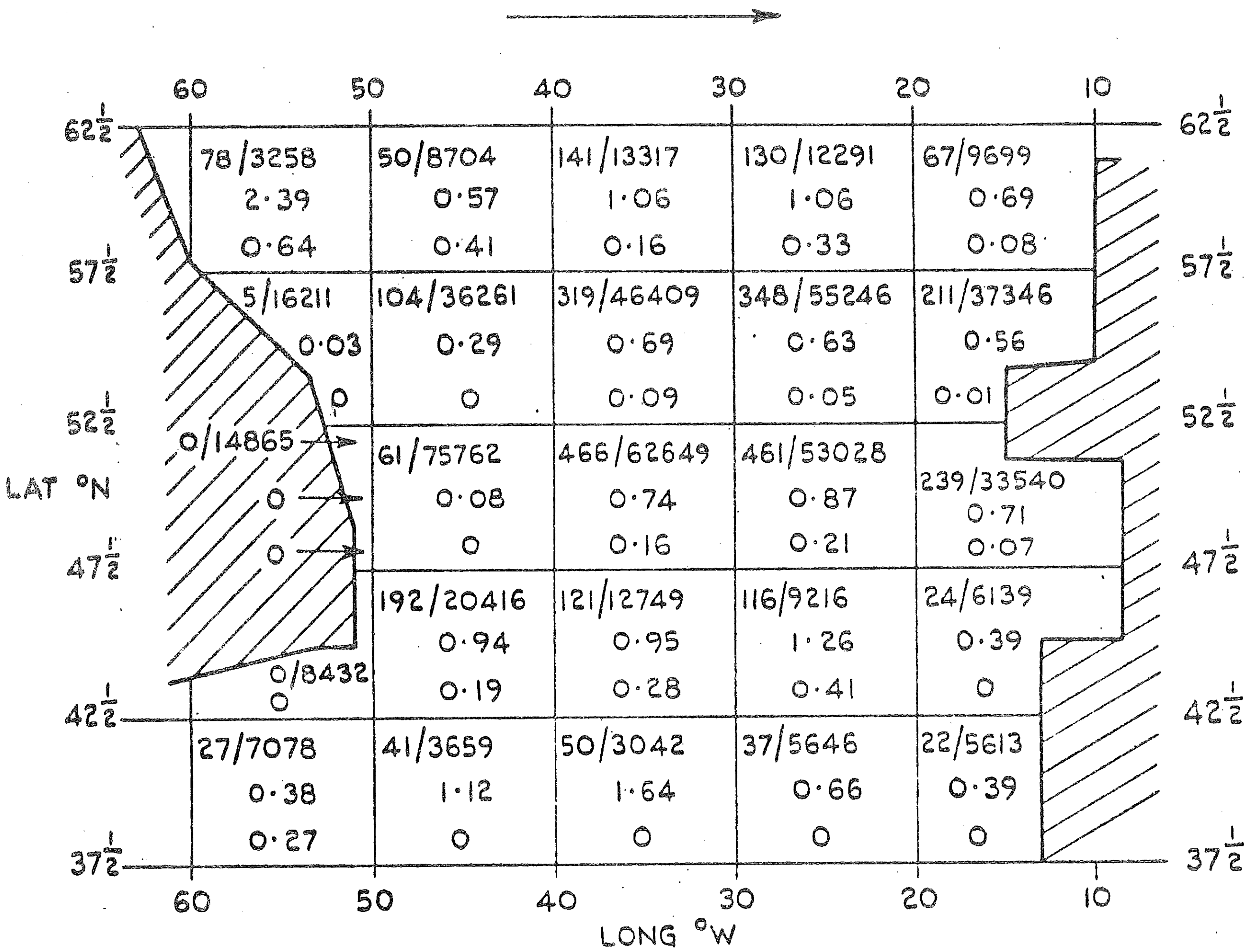


Table 1.21

OCCUPANCIES CALCULATED BY RAE FOR 40°W AND 20°W

Longitude	Latitude bands				
40°W	62° and above	57°-61°	52°-56°	45°-51°	up to 44°
E_y (same)	0.28	0.56	0.72	0.63	0.00
E_y (opposite)	0.00	0.00	0	0.01	0.00

Longitude	Latitude bands				
20°W	57° and above	53°-56°	49°-52°	42°-48°	42°-46°
E_y (same)	0.56	0.76	0.72	0.19	0.03
E_y (opposite)	0.00	0.02	0.01	0.00	0.00

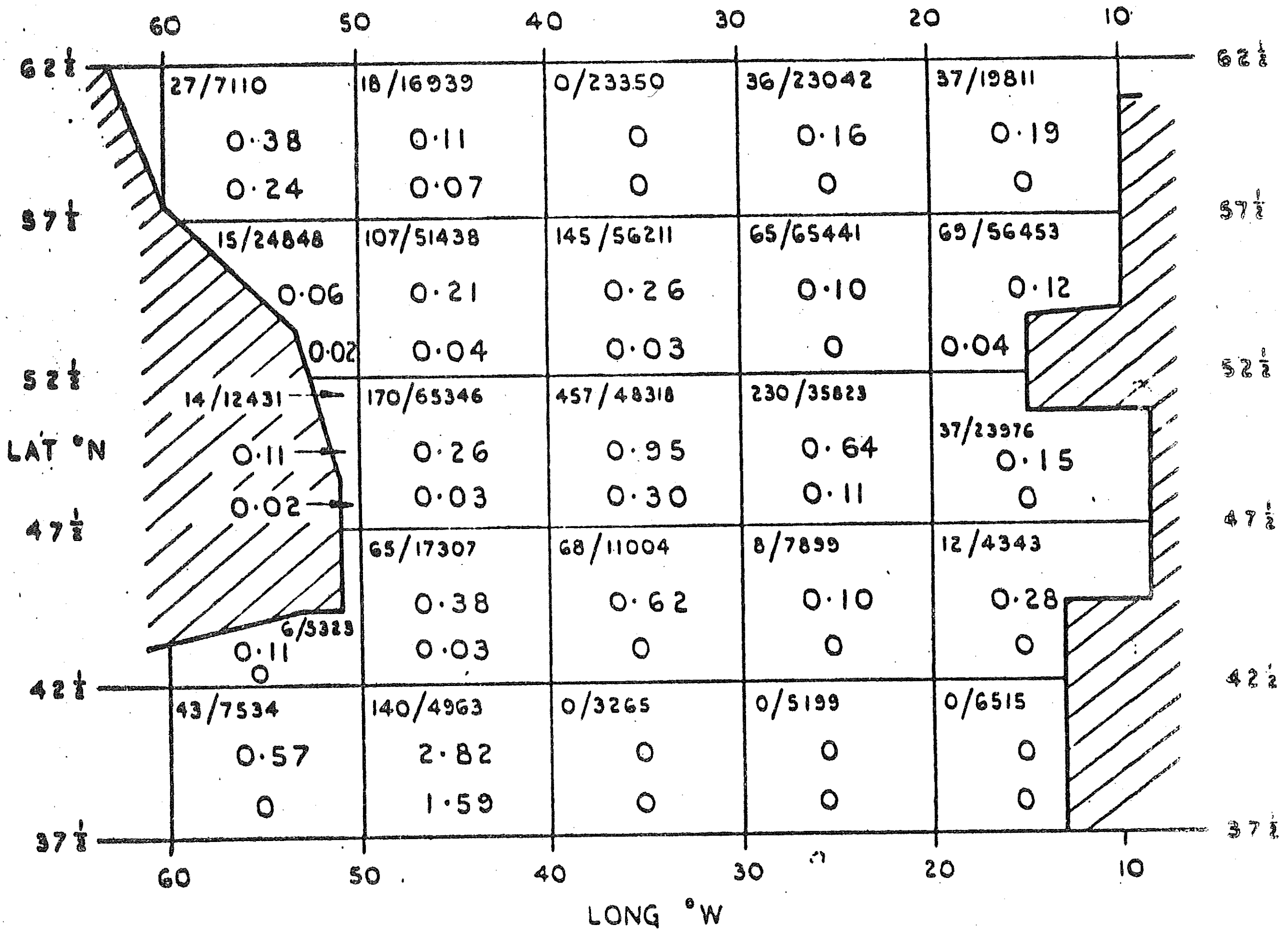


KEY

Time ≥ 30 nm off track / Total flying time in area (minutes)
% time spent ≥ 30 nm off track
% time spent ≥ 45 nm off track

Indicated proportion of time in whole area ≥ 30 nm off track = 0·59%
Indicated proportion of time in whole area ≥ 45 nm off track = 0·10%
Indicated proportion of time in whole area ≥ 60 nm off track = 0·02%

Fig. 1.22 Evidence on across-track deviations on eastbound flights, from 2943 forms 1-D



KEY

Time ≥ 30 n.m. off track / Total flying time in area (minutes)

% time spent ≥ 30 n.m off track

% time spent ≥ 45 n.m off track

Indicated proportion of time in whole area ≥ 30n.m. off track = 0·29%

Indicated proportion of time in whole area ≥ 45nm. off track = 0·06%

Indicated proportion of time in whole area ≥ 60nm off track = 0·01%

Fig. 1.23 Evidence on across-track deviations on westbound flights, from 2992 forms 1-D

60°W	50°W	40°W	30°W	20°W	10°W 62°½N
E X W A	½ A ½ B	B	½ B ½ D	W X E D	½N
E X W A	½ A ½ B	B	½ B ½ D	W X E D	52°½N
E X W A	½ A ¼ B ¼ C	½ B ½ C	¼ B ¼ C ½ D	W X E D	47°½N
E X W A	½ A ½ C	C	½ C ½ D	W X E D	42°½N
E X W A	X	X	1/3 C 1/3 D 1/3 H	H	37°½N

<u>Code</u> : E - Eastbound

W - Westbound

A - Gander

B - two ships at 35°W (53°N and 58°N)

C - ship at 35°W and 48°N

D - Kilkee

H - Humboldt II

X - Not counted

(Where no E or W appears, the values apply to both eastbound and westbound).

Table 1.24

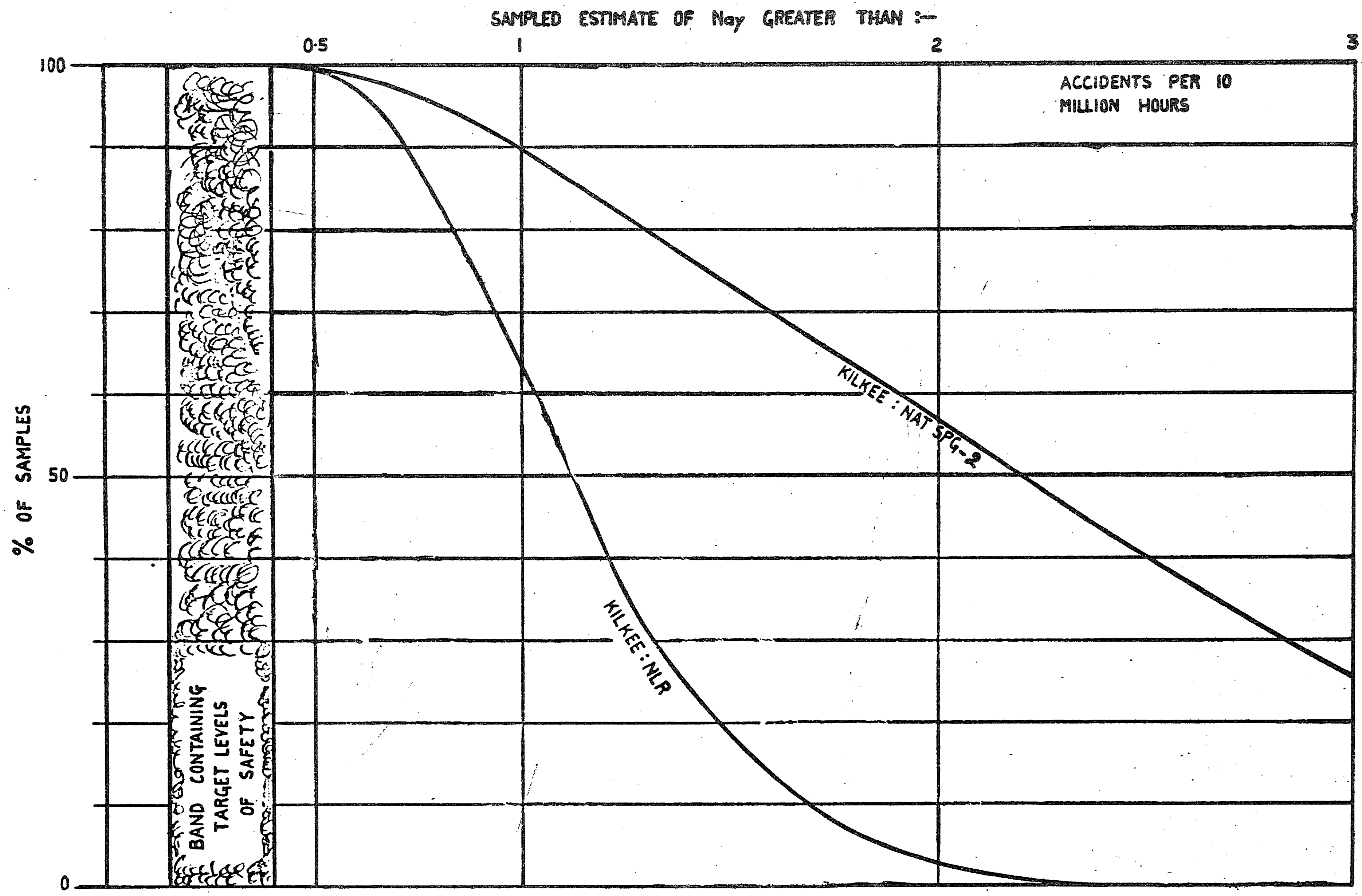


FIG 1.25 D.S. COLLISION RISK ESTIMATES FOR KILKEE DATA BY NLR & SPG-2 METHODS
(90nm LATERAL SEPARATION STANDARD)

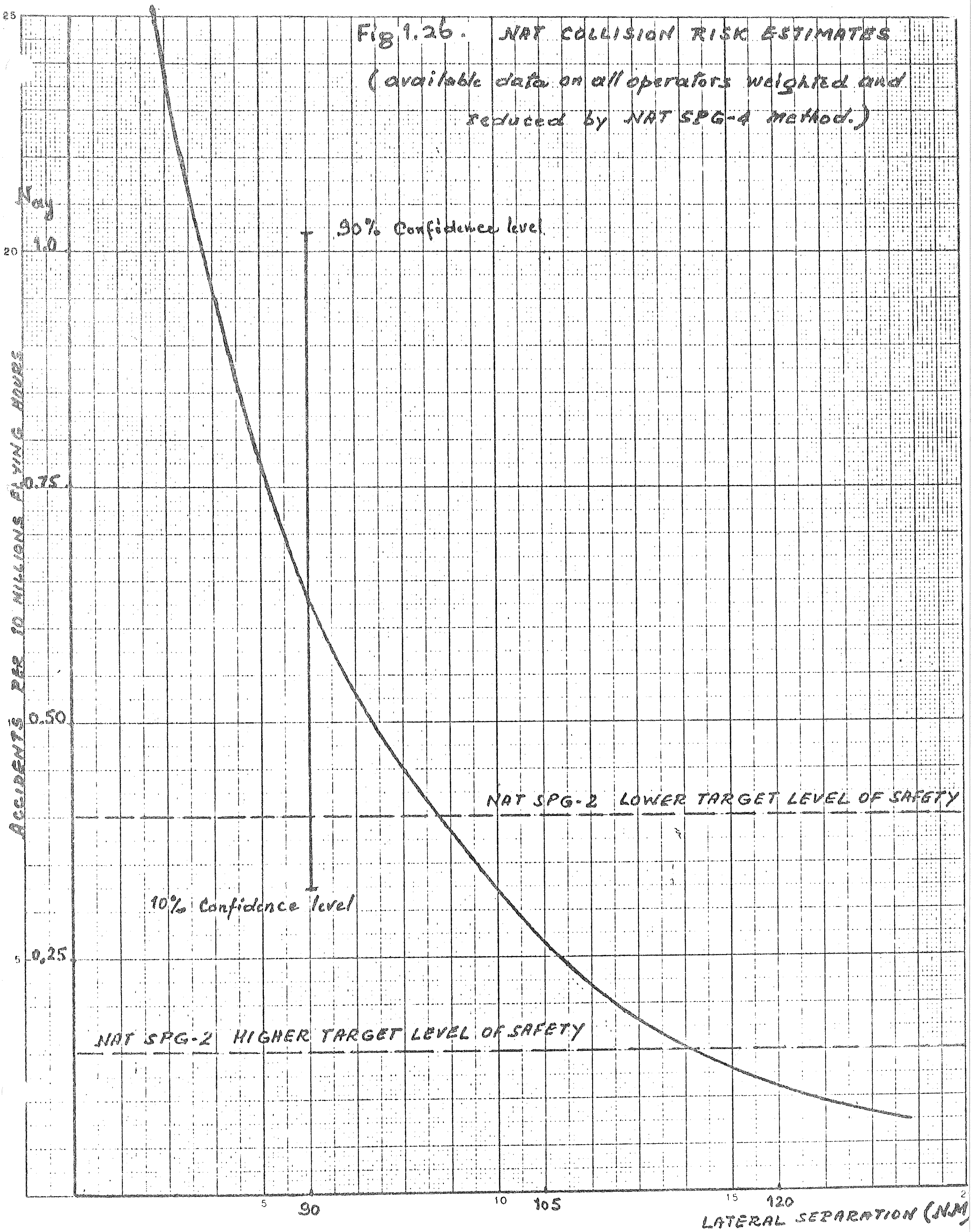


Fig 1.26. NAT COLLISION RISK ESTIMATES
(available data on all operators weighted and reduced by NAT SPG-4 method.)
N_{ay}
1.0
0.75
0.50
0.25
ACCIDENTS PER 10 MILLIONS FLYING HOURS
90% Confidence level
10% Confidence level
NAT SPG-2 LOWER TARGET LEVEL OF SAFETY
NAT SPG-2 HIGHER TARGET LEVEL OF SAFETY
90
105
120
LATERAL SEPARATION (N.M)

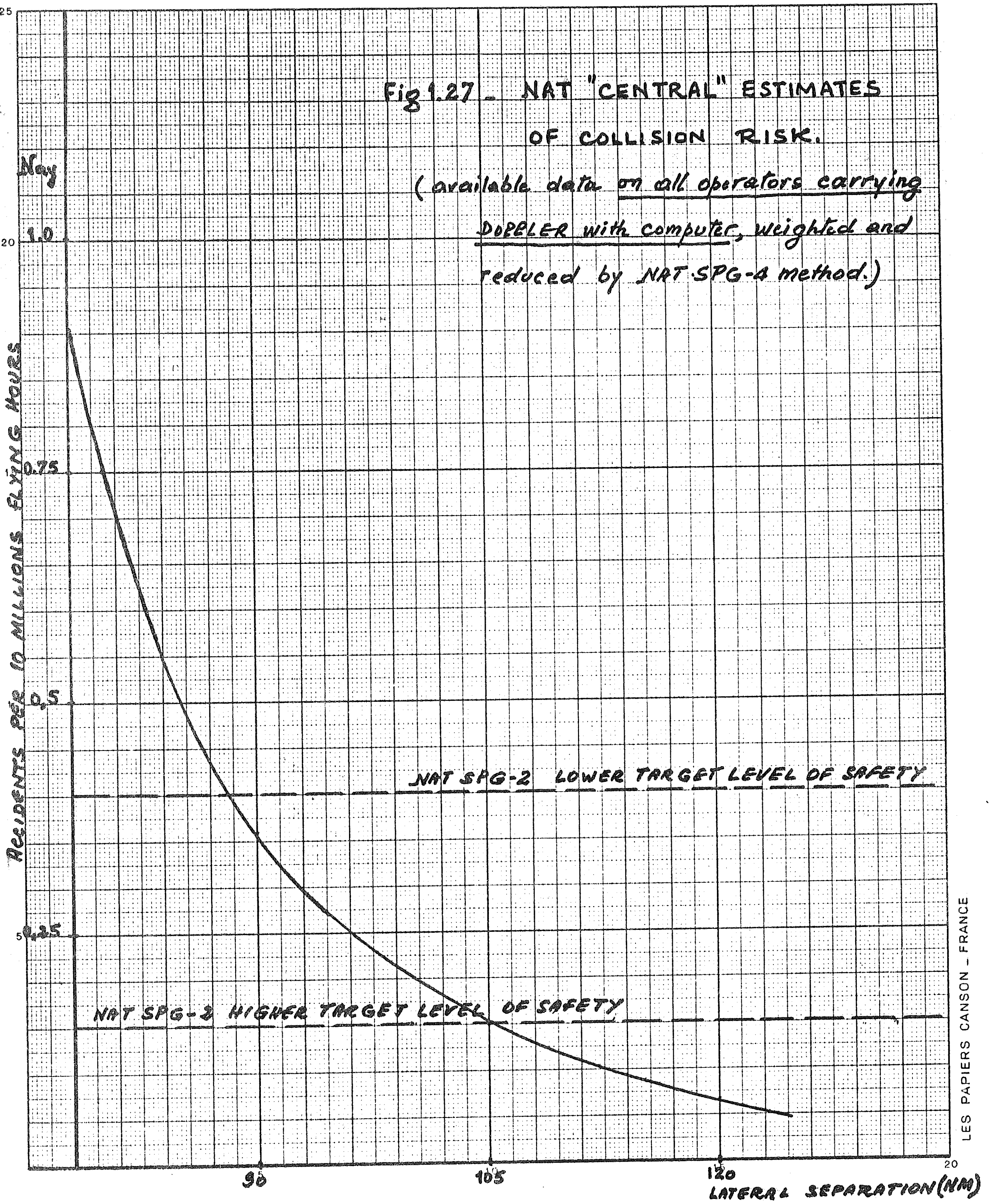


Fig 1.27 _ NAT "CENTRAL" ESTIMATES
OF COLLISION RISK.
(available data on all operators carrying
DOPPLER with computer, weighted and
reduced by NAT SPG-4 method.)
Nay
1.0
0.75
0.5
0.25
ACCIDENTS PER 10 MILLIONS FLYING HOURS
NAT SPG-2 LOWER TARGET LEVEL OF SAFETY
NAT SPG-2 HIGHER TARGET LEVEL OF SAFETY
90
105
120
LATERAL SEPARATION (NM)
LES PAPIERS CANSON _ FRANCE

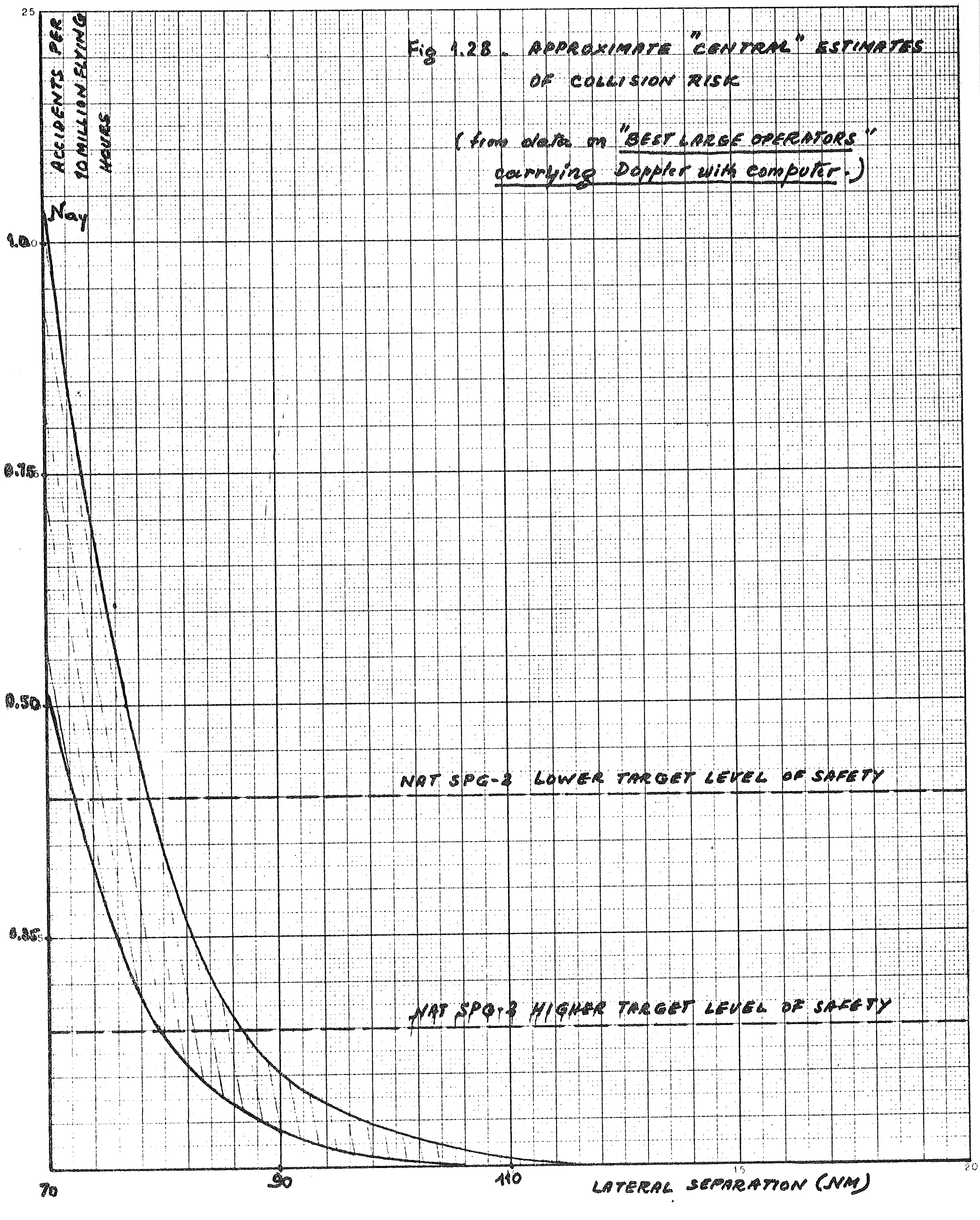


Fig 1.28. APPROXIMATE "CENTRAL" ESTIMATES OF COLLISION RISK
(from data on "BEST LARGE OPERATORS" carrying Doppler with computer.)
ACCIDENTS PER 10 MILLION FLYING HOURS
Nay
1.00
0.75
0.50
0.25
NAT SPG-2 LOWER TARGET LEVEL OF SAFETY
NAT SPG-2 HIGHER TARGET LEVEL OF SAFETY
70
90
110
LATERAL SEPARATION (NM)

2. <u>Summary of Agenda Item 2</u> : Review of the situation concerning the continued operation of Loran A chain Charlie

2.1 <u>Introduction</u>

2.1.1 With reference to Recommendation 6iii/5 of the Special NAT Meeting 1965 concerning the continued operation of Loran A chains "Charlie" and "Delta", the 2. Meeting of the NAT/SPG, held in November-December 1966, had been notified that preparations were under way by the administrations concerned to put these chains into continuous operation but that not all of the very complex technical difficulties had as yet been overcome.

2.1.2 At the beginning of the data collection exercise, chains "Charlie" and "Delta" were put into continuous operation. However, whereas chain "Delta" continues to function in this mode, chain "Charlie" had to revert to intermittent operation on 1. December 1967 because of the problem of interference of this chain with certain maritime mobile services. Arrangements were however made to try to reduce this interference by modification to the Loran transmitters. Action was taken by the U.S. Coast Guard in cooperation with the French and U.K. authorities and the results tested in April 1968 aboard the RFA "Engadine" with interested parties present. It was found that a significant reduction in interference levels had been achieved. The U.K. member informed the Group that although interference with U.K. maritime mobile services was still present, 24 hour operation of the chain was now acceptable to the U.K. authorities provided that an assurance was given that the improvements in Loran transmissions were maintained and appropriately monitored. (It is understood that this assurance has been given). He also indicated that it was intended to take steps to improve the shore based marine station equipment to further reduce the remaining effects of Loran interference and asked that this be taken into account in considering the date of introduction of 24 hour operation.

2.1.3 The Group also noted that there was action under way by the parties directly concerned to have Loran A chains "Charlie" and "Delta" included in the NAT Regional Plan and it was expected that an amendment to the plan to this effect could be made in the near future.

2.2 Review of the operational requirement for the continued operation of the chains

2.2.1 The Group confirmed that Loran A chains "Charlie" and "Delta" constituted an essential element of the navigation system in the NAT Region and will therefore have to be put on a 24 hour operating basis if navigational accuracy in the area covered by these chains is to be maintained (the approximate ground wave cover of these chains, together with that provided by others, is shown on the chart on page 2-A-1).

2.2.2 In addition the Group confirmed that there was no indication that this requirement was likely to cease in the foreseeable future.

2.3 Conclusion

2.3.1 In view of the above considerations, the Group came to the following conclusions :

i) the operational requirement for Loran A chains "Charlie" and "Delta" expressed at the Special NAT Meeting 1965 of ICAO is fully confirmed;

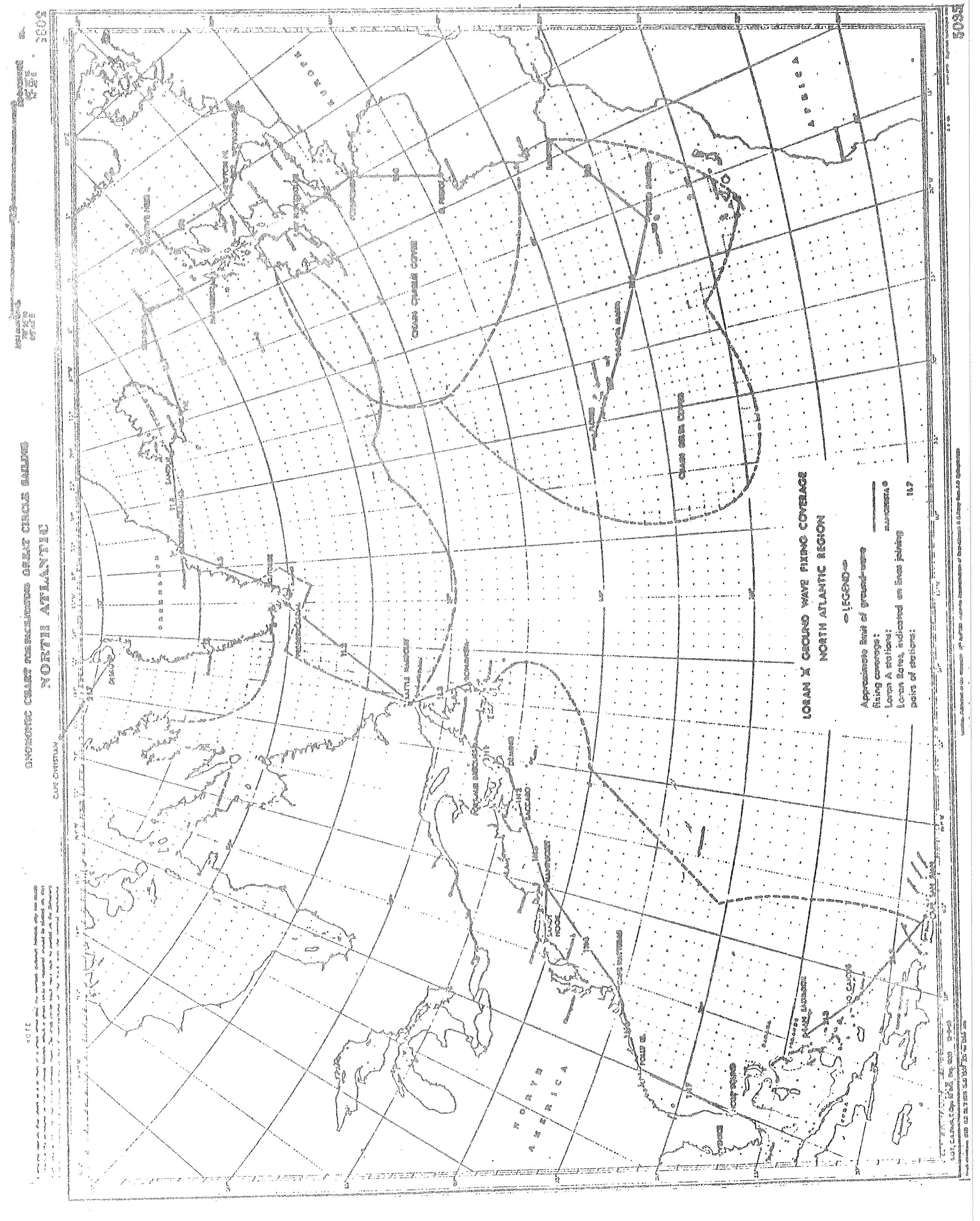
ii) there is no indication that this requirement will cease to exist in the foreseeable future;

iii) as a consequence of i) and ii) the administrations concerned are urged to take all necessary measures to put these chains into full-time 24 hour operation;

iv) in view of the significance of these two chains for the accuracy of navigation in that area wherein they provide cover, it is hoped that the administrations concerned will be able to comply with conclusion iii) as soon as possible and, in any event, not later than by 19 September 1968.

Figure 2.1

LORAN A COVER IN THE NAT REGION



3. Summary of Agenda Item 3 : Assessment of the effectiveness of the new air reporting procedures applied on a trial basis in the NAT Region

3.1 Introduction

3.1.1 Because of numerous complaints about the complication and confusion surrounding this subject, the 3rd Meeting of the NAT/SPG, held in April 1967, had made a detailed review of the Air Reporting procedures applied in the NAT Region. As a consequence of this review, the Group had developed an amended procedure, taking into account applicable ATS, MET and COM aspects as necessary. (See summary of Agenda Item 3 of the 3rd Meeting of the NAT/SPG). However, in order to avoid a further modification of the formal procedures, should this be found necessary in actual operation, it was agreed that these revised procedures should initially be implemented on a trial basis only and that formal action for their inclusion in ICAO, DOC. 7030 should only be made once they had been found satisfactory.

3.1.2 In Summer 1967 preparations by the provider States had been completed and the new procedures were introduced and have been in use since.

3.2 Review of the results obtained with the new procedures

3.2.1 Based on information provided by some of its members and the users represented at the meeting, the Group agreed that the revised procedures themselves had been found fully satisfactory. It was also noted, with particular satisfaction, that a number of national meteorological services, closely concerned with NAT operations, had indicated that they were in full agreement with these procedures and considered them to be adequate.

3.2.2 The only point which was not yet fully resolved was, that compliance by pilots with the new procedures still left something to be desired. It was for instance noted that only about 80% of those aircraft operating in the organized track system fully complied with the new procedures, while the rest still tended to transmit more information, and in particular MET data, which was not required.

3.3 Remaining problems

3.3.1 In the course of the discussions, IATA raised the question, whether there was still a requirement for the systematic inclusion of the "estimated time over the next position" in each position report. The United Kingdom member pointed out that, while there was no real need for this information concerning those aircraft operating in the organized track system, this information was however essential for all aircraft operating on crossing tracks or outside the system. In addition it was pointed out that the "estimated time over", constituted an integral part of the position report as defined in Annex 3 and it would therefore be necessary to amend this document first before the "estimated time over" could be deleted from a position report.

3.3.2 In view of the fact that the elimination of the time would only be feasible for position reports made by aircraft in the organized track system, thus introducing a further difference in position reporting in the NAT Region, this point was not pursued. It was however noted that this point might also apply to position reporting by aircraft operating on the continental ATS route network and that it might therefore be useful, in a general way, to pursue this subject further in an appropriate forum of ICAO (possibly the 6th AN Conference) with a view to improving radio telephony procedures in general.

3.3.3 As regards the identification of spot winds in aircraft observations, raised in para. 3.4.1.2 on page 3-6 of the Summary of the 3rd Meeting of the Group, it was noted that action on this was still outstanding.

3.4 Action required

3.4.1 In view of the above, the Group agreed that the following action should be taken :

i) in accordance with para. 3.6.3 of the Summary of the 3rd Meeting of the NAT/SPG the United Kingdom will propose an amendment to DOC. 7030 in accordance with Appendix B to that Summary;

ii) upon approval of the amendment, provider States will issue a NOTAM indicating the definitive application of the new procedure. Simultaneously these States will also issue an information circular in accordance with Appendix A to the Summary of discussions on Item 3 of the 3rd Meeting of the NAT/SPG, except that the diagram forming Appendix A to the Information Circular shall not incorporate examples of the Air Reporting Procedure required on specific routes;

Note : The latter decision was taken since it was felt that because of the changes likely to occur with respect to various reporting points the inclusion of such examples would render the information circular obsolete unless it was up dated at frequent intervals for this purpose only.

iii) provider States not having already done so should forward to the Paris Regional Office as soon as possible maps showing the area of cover provided related to height, by VHF air-ground communication stations used in the NAT Region and operated by the States concerned in order to allow early preparation of the consolidated chart which should be added to the Information Circular mentioned under ii) above. A sample of such a chart will be prepared by the Paris Regional Office and forwarded, together with individual charts as submitted by States, to the provided States as soon as possible after receipt of all individual cover charts.

Figure 3.1

VHF COVER FROM SHANNON AT FL 300 AND ABOVE

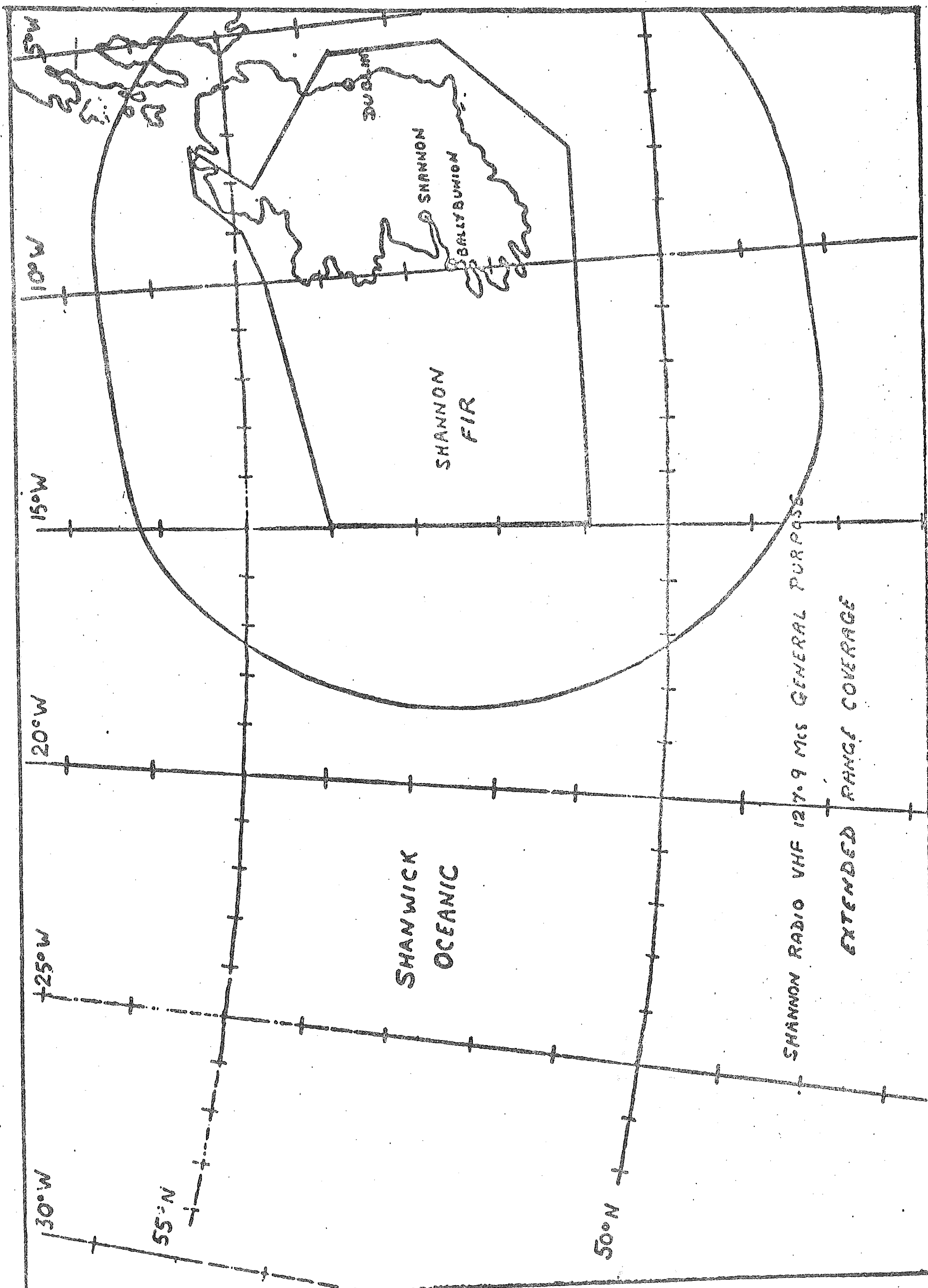
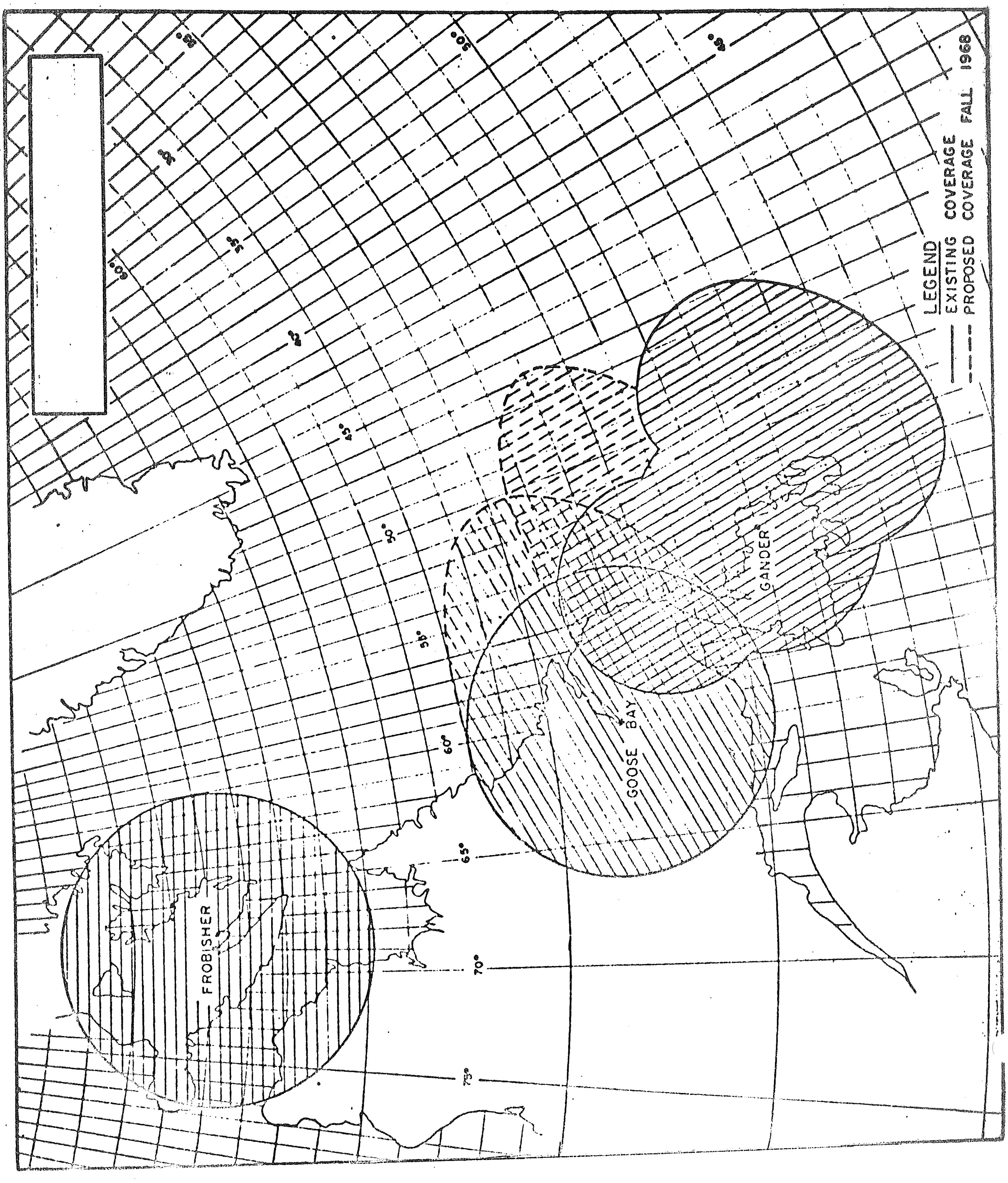


Figure 3.2

INTERNATIONAL VHF COVER FOR AIRCRAFT FLYING AT FL 300 OR HIGHER



4. Summary of Agenda Item 4 : Development of a method for the determination of longitudinal separation standards in the NAT Region.

4.1 Introduction

4.1.1 At its 3rd Meeting, the Group had been presented with a paper by its French member proposing a method of mathematical treatment of data on longitudinal separation expected to be obtained during the data collection programme. In view of the time-schedule it had, however, not been possible to give this proposal any detailed consideration and it had therefore been agreed that this matter should be more thoroughly discussed at the 4. Meeting.

4.1.2 In the light of documentation presented to the Group at this meeting, and mainly that prepared by its member from the United Kingdom, the Group agreed to slightly enlarge this agenda item and review the question of longitudinal separation also from its operational aspects and not only from the mathematical/statistical one. For this reason the summary has been subdivided into an operational and a mathematical/statistical section.

4.2 Review of the problem of longitudinal separation under operational aspects

Existing situation

4.2.1 The Group noted that, at the present time, the following situation existed :

i) for jet aircraft operating on the same or diverging tracks 15 minutes longitudinal separation associated with the Mach number technique is applied in certain parts of the region

ii) for all other traffic by jet aircraft operating south of 70°N the ICAO Council, based on a recommendation of the Special NAT Meeting 1965, adopted a longitudinal separation of 20 minutes with the proviso that this should be applied as soon as the provider States had reached agreement on a common date of application;

iii) for other than turbo-jet aircraft operating in the New York Oceanic Control area 20 minutes are used when operating on routes between the United States, Canada or Bermuda and Caribbean terminals or between the United States or Canada and Bermuda;

iv) for all other traffic, not covered by i), ii) and iii) above, 30 minutes are applied.

4.2.2 While the provisions in i), iii) and iv) above are already implemented, no agreement has as yet been reached regarding the implementation of ii) despite a number of efforts to this end by the ICAO Secretariat and at least one of the provider States (see para. 4.2.10).

4.2.3 It was also noted that there was a requirement to extend the application of the provision in para. 4.2.1 i) to the New York Oceanic Control Area. It was therefore suggested that the U.S.A. consider the feasibility of a proposal for amendment of the appropriate SUPPs in DOC 7030.

Review of the 15 minutes case

4.2.4 The Group was informed that, even though the theoretical capacity per hour of the organized track system with the application of the datum line was 64 aircraft per hour, (4 aircraft per hour on each of 4 levels of 4 tracks = 4x4x4 = 64), experience had shown that due to the random arrival of aircraft over the entry points into the system the average number of aircraft which could be accommodated was only slightly over 32 aircraft per hour.

4.2.5 It was also noted that any possible decrease in this type of longitudinal separation, while increasing the traffic capacity of the organized track system, would not result in any new application problems for ATC, except that it might cause traffic integration problems at either limit of the NAT Region and increase the difficulties now encountered regarding the accommodation of flights operating on tracks crossing the organized track system.

4.2.6 As regards the possibility of decreasing this type of longitudinal separation, the United Kingdom member presented to the Group a study which had been made in the United Kingdom regarding the use of navigation equipment already available in most aircraft for determining an aircraft's position in relation to other aircraft, preceding or following it along the same track. The navigation equipments so reviewed were:

i) DME
ii) SSR
iii) Airborne Weather Radar

and possible combinations of these equipments.

4.2.7 Preliminary studies had shown that the use of DME for the purpose in question appeared to be most promising since :

i) it required only very small and inexpensive modifications to the airborne installations ;
ii) the identification of aircraft participating in a system using this method is automatic.

Other possibilities examined appear to be more costly and technically much more complicated.

4.2.8 The concept of the use of DME for the purpose of position determination of an aircraft with respect to others is briefly the following :

i) Each aircraft would need to be fitted with two DME equipments (this is already widely practiced) which would be modified so as to be capable of acting either as transponder or interrogator. On departure, the aircraft would be assigned a DME 'Y' Mode frequency (there are at least 100 Channels available for unrestricted civil use in all so there is no shortage of frequencies) on which one of the DME facilities on board would remain acting as a transponder during flight in the Oceanic airspace. Thus the frequency assigned in effect identifies the aircraft concerned ; this information can be passed by ATC to any other interested aircraft on the particular assigned track. The next aircraft to depart would be identified by the next available DME frequency, and so on. By allocating 'blocks' of frequencies to particular flight levels and tracks, the ATC services would ensure that non-significant input was not received.

ii) The crew of an aircraft so equipped could interrogate an aircraft immediately in front of or behind it in the procession across the Atlantic and obtain almost instantaneous range information from them. The air-to-air range of the system would probably be of the order of 200 miles.

4.2.9 Even though it was believed that this study was very interesting, some members felt that it required further review before they would be able to discuss it in necessary details and it was therefore agreed that this question should be given further consideration at the next meeting of the Group.

Review of the 20 minutes for jet-traffic case south of 70°N

4.2.10 As already stated in para. 4.2.2 this is the only case of agreed longitudinal separation which has as yet not been implemented for, as it would appear, purely administrative reasons. At the same time, it was noted that the present retention of 30 minutes was causing considerable difficulties to the oceanic ACC's since the application of such a large separation, especially to aircraft which were operating on tracks crossing those of the organized track system, frequently required extensive re-planning of the entire traffic flow affected by the flight concerned with subsequent re-clearances to a number of aircraft and this under communications conditions which were sometimes difficult.

4.2.11 It was therefore believed that the early application of the agreed minimum of 20 minutes would not only materially assist the ATC units concerned by simplifying their work, but would also be of benefit to air traffic in general since it would appreciably reduce the number of cases where ATC was required to interfere with the intentions of pilots.

Review of the effects of speed differences between various types of aircraft

4.2.12 No definite information was yet available on the cruising speeds of new types of aircraft ("jumbo-jets") intended for use in the NAT Region. It would be necessary to develop procedures to enable ATC to deal with the problem of integrating such aircraft into the organized track system.

4.2.13 It may therefore be necessary to reach agreement not only on the tactical measures provided to ATC to cater for this situation, such as a possible reduction of longitudinal separation at the entry point into the NAT Region between a preceeding faster and a succeeding slower aircraft following the same track, but also on the mathematical/statistical methods by which the appropriate definite values, expressed in minutes of time, should be established.

Effects on the mathematical/statistical methods from the proposal to use DME or other airborne equipment for the determination of relative positions of aircraft

4.2.14 Finally it was noted that, should the proposal described in para. 4.2.8 prove worthy of development, it would be necessary to take this into account in the mathematical/statistical approach to the question of longitudinal separation since this might not only alter some of the presently accepted mathematical factors significantly but might also introduce completely new factors related to equipment reliability.

4.3 Conclusions concerning the operational aspects of longitudinal separation

4.3.1 As regards the general application of 20 minutes longitudinal separation to turbo-jet aircraft operating south of 70°N in the NAT Region, the Group agreed that the provider States concerned should, as a matter of urgency, review this matter in order to obtain agreement on a common date of application which should be as early as possible.

4.3.2 With regard to the proposal by the United Kingdom member concerning the use of DME for the determination of the relative position of aircraft, the Group agreed that this matter should be reviewed by members, including its mathematical/statistical aspects, in order to allow its detailed consideration by the Group at its next meeting.

4.3.3 Concerning the question of speed differences between various types of aircraft, and their effect on the application of longitudinal separation, the Group agreed that this should also be further studied with a view to developing adequate ATC procedures, taking into account mathematical/statistical considerations as appropriate.

4.4 Mathematical/Statistical aspects of the longitudinal separation

4.4.1 The collision risk equation

4.4.1.1 The Group agreed that many of the basic principles described in the Summary of Discussions on Agenda Item 4 of the second meeting (ref.21) are valid for assessing the longitudinal separation standards :

4.4.1.2 The general equation of the risk is :

$$CR = N_x\,(std)\,P_y(o)\,P_z(o) + N_y(o)\,P_z(o)\,P_x(std) + N_z(o)\,P_x(std)\,P_y(o)$$

Assuming that the probability density function of the along-track deviation is constant over $2\lambda_x$, the collision risk equation can be written as follows :

$$(CR)_x = \left[\frac{\overline{|\dot{x}|}}{2\lambda_x} + \frac{\overline{|\dot{y}|}}{2\lambda_y} + \frac{\overline{|\dot{z}|}}{2\lambda_z}\right] P_x(std)\;P_y(o)\;P_z(o)$$

4.4.1.3 Replacing $P_x(std)$ by $\sum_t P_x(t)\;E_x(t)$ the equation becomes:

$$N_{ax} = 10^7\left[\frac{\overline{|\dot{x}|}}{2\lambda_x} + \frac{\overline{|\dot{y}|}}{2\lambda_y} + \frac{\overline{|\dot{z}|}}{2\;\;_z}\right] P_y(o)\;P_z(o).\sum_t P_x(t)\;E_x(t)$$

where

N_{ax} is the number of accidents per 10 million aircraft flying hours, due to loss of longitudinal separation.

$\overline{|\dot{x}|}, \overline{|\dot{y}|}, \overline{|\dot{z}|}$ are the mean modulus values of the relative along-track, across-track and vertical speeds.

λ_x, λ_y and λ_z are the length, width and thickness of the collision slab.

$P_x(t)$ is the probability that along-track separation of a pair of aircraft, initially separated by an amount t plus an allowance for Mach nb. difference, is less than λ_x.

$E_x(t)$ is the average number of aircraft that a given reference aircraft will have on the same track and flight level with initial separation t plus an allowance for Mach number difference.

$P_y(o)$ is the lateral overlap probability that a pair of aircraft assigned to the same track are separated in the lateral dimension by less than λ_y.

$P_z(o)$ is the probability of vertical overlap.

4.4.2 Discussion of the parameters

4.4.2.1 $\dot{y}$: The relative across-track velocity

A value of 20 kts of this parameter has been deduced from figure 1.16 page 1-A-19. Since this value is smaller than the value of 60 kts appropriate to the lateral case, it will be necessary to use more precise estimates of $|\dot{x}|$ and $|\dot{z}|$, for the longitudinal case.

4.4.2.2 $\dot{z}$: The relative vertical speed

4.4.2.2.1 It was pointed out that the method used in the lateral risk calculations to estimate N_z from only the phugoïd frequency ($f = 40$ cycles per hour) is not logical. Both quantities N_z and f have the same dimensionality, T^{-1}, but an estimation cannot be made without using also a value for the phugoïd amplitude, A. From both $\omega = 2\pi f$ and A, it is possible to calculate $\overline{|\dot{z}|} = 8\, A\omega/\pi^2$

4.4.2.2.2 Present knowledge of frequency and amplitude therefore indicate a value $\dot{z}$ nearly equal to 1 knot, which agrees with a revised estimate of $\dot{z}$ by RAE (ref. 17 in list of reference documents on page 11 - 2). This value of 1 knot gives:

$$N_z\ (o) = \overline{|\dot{z}|}\ P_z\ (o)\ /\ 2\lambda_z \ = \ 20 \text{ cycles per hour,}$$

in contrast to the central value $N_z\ (o) = 40$ cycles per hour with range from 20 to 60, which has been used in the calculations of the lateral risk.

4.4.2.2.3 Although the above correction would reduce the lateral risk by only a few percent, it will have a greater effect in the longitudinal risk calculations. The Group therefore agreed to use $N_z(o) = 20$ cycles per hour for all lateral and longitudinal future risk calculations and more generally to use $\overline{|\dot{z}|} = 1$ knot for other appropriate N_z's for the vertical risk.

4.4.2.3 The relative along track velocity $\dot{x}$

4.4.2.3.1 $\dot{x}$ is the average relative along-track velocity of a pair of aircraft which collide due to loss of longitudinal separation. The Group agreed that the value of 13 knots which has been used for lateral collision risk calculations was no longer appropriate to longitudinal separation since $\dot{x}$ must be larger if longitudinal separation is ever to be lost. The Group agreed that an appropriate value would have to be estimated by a method based on pairs of aircraft which had lost a considerable amount of lateral separation. In order to investigate the applicability of the evidence to the collision situation it would be necessary to assess the importance of the component of $\dot{x}$ due to wind shear. A method of estimating the effect of local wind variations was put forward, which involved examining flight records of local "clusters" of Doppler - equipped aircraft for evidence of wind shear.

4.4.2.3.2 In this respect, the recommendation in paragraph 7.2.4, page 7-2-4-1 relating to the retention of flight records is relevant.

4.4.2.4 The probability of lateral overlap $P_y(o)$

A value of $P_y(o)$ can be accurately calculated from the information already available on lateral deviations distribution. The Group however noted that an increase in this value is to be expected in the future following improvements in means of navigation.

4.4.2.5 The probability of vertical overlap $P_z(o)$

The Group agreed during its second meeting to retain value of 0.25 for this parameter.

4.4.2.6 The probability of longitudinal overlap $P_x(t)$

4.4.2.6.1 The Group agreed that unlike the lateral case where convolution of measured deviations of single aircraft was appropriate, it will be necessary in the case of longitudinal separation to use a measure of relative along-track positions of a pair of aircraft.

4.4.2.6.2 In this respect, The Group decided to use the data obtained during the last data collection exercise. However, the estimation of P_x presents formidable difficulties arising from the very large number of observations required. It was agreed that it was necessary to study pairs of aircraft which must be representative of pairs assigned at relatively small longitudinal separations. Aircraft on adjacent tracks should not be included and after a discussion of the influence of wind shear it was agreed that aircraft on adjacent flight levels should not be used. The along-track criterion for a proximate pair should have some value, probably in the range 30 to 60 minutes, to be chosen on the basis of preliminary study. The choice would be a compromise between sample size and strict validity. It was however pointed out that an increase in the sample size by this means would result in cautious estimates.

4.4.2.6.3 The study of proximate pairs would be undertaken as follows :

a) A search would be made for "proximate pairs" of aircraft, defined as described above and for each such pair the "initial separation" is defined as the difference between the ACC's understanding of the times at the start of the track. For westbound aircraft this is the aircraft's reported time (ATO). The actual separation is defined as the difference between true times of the aircraft over some meridian, and can best be estimated from the radar records produced for the lateral separation exercise. The loss or gain of separation is defined as the difference between actual separation and initial separation, allowing for differences in assigned Mach number. The allowance for this difference should be that used by the air traffic controllers. (believed to be 3 mins per 0.01 M for a complete crossing of the Atlantic)

b) A distribution of gains and losses of separation would be produced (after careful checking of large values). If ATC regulations were strictly adhered to this should be a symmetric distribution, so the distribution of gains would be representative of the distribution of losses, and the effective sample size would be doubled. The question of whether gains should be taken as representative of losses could be decided after examining the data.

4.4.2.7 Occupancy (E_x)

4.4.2.7.1 The control system is such that a single value for "occupancy" is not appropriate to the longitudinal problem. It is necessary to use a frequency-distribution of "initial separation", adjusted for assigned Mach number differences. This distribution will have to be convolved with the "separation loss" distribution to give the probability of longitudinal overlap P_x. It is likely that the separation loss will be correlated with initial separation and thus that the estimates obtained will be pessimistic.

4.4.2.7.2 The Group noted that in the lateral study it had not been possible to find sufficient proximate pairs to provide a reasonable estimate of collision risk, which took into account the correlation between across-track errors. It seems likely that a similar situation will occur in the longitudinal case, and since it is essential that the longitudinal study be based on proximate pairs, it is possible that insufficient pertinent data will be available for estimates of reasonable confidence.

4.4.2.8 Conclusion

4.4.2.8.1 It is quite possible that the size of the available sample could be insufficient for assessing the present level of risk or for computing with reasonable confidence limits the level of risk associated with a shorter separation standard.

4.4.2.8.2 Assessment of the station-keeping system described in para. 4.2.7 would require a different mathematical/statistical approach but analysis of the existing data would provide evidence on some of the relevant parameters.

4.4.2.8.3 It is proposed that the analysing of the available data from all sources should be undertaken and, if the first results are encouraging enough, conducted to its end. In any case this exercise will be of great interest for future planning.

4.4.2.8.4 Since the subject of longitudinal separation is included in the tentative agenda of the next Meeting of the Group (see para. 9.2) the Group invited the RAE to prepare a report on this subject for this Meeting.

5. Summary of Agenda Item 5 : Exchange of views on a possible work programme of the NAT/SPG regarding SST operations in the NAT Region and development of a programme of preparatory measures, as necessary.

5.1 Introduction

5.1.1 With the introduction of Concorde in 1971 and the anticipated growth of SST operations on North Atlantic routes through the 1970's, the Group believed that it was important to give early attention to this subject both in relation to the needs of this type of aircraft, and the interrelation of its operation with that of subsonic jet traffic.

5.1.2 The proposed NAT RAN meeting can be expected to cover this field but for a successful outcome preparatory work will be needed, some of which is appropriate to the NAT Systems Planning Group. It was therefore agreed to discuss this subject at the Group's next meeting.

5.1.3 As it was agreed that, in order to ensure effective discussion, adequate documentation was required, preferably well ahead of the meeting, working papers providing information on subjects such as the performance (profiles) of the Concorde relevant to the Group's work, an assessment of ATC problem areas and possible solutions, including possible route structures and other relevant subjects should be made available as early as possible. It was also hoped that members concerned will keep close contact with any national or international agency with which they are concerned and which is doing work in the same field so that duplication of effort is avoided. It was also noted that the U.K. member had already documentation for initial consideration at the next meeting of the Group.

5.1.4 Although the extent to which States will permit supersonic flight overland, or what form any restrictions might take, may not be clear by the time of the next meeting of the Group, nevertheless in the first instance it is believed that discussion should proceed on the following bases:

1) Consideration of the consequences, in respect to NAT air traffic services, of no supersonic flight overland.

2) No superbang overland implying supersonic transition outbound, over sea, but otherwise supersonic flight permitted overland.

5.1.5 The deployment of facilities and areas requiring special attention in the development of ATC procedures, will need to be determined. It seems that, at least for initial operations of Concorde, the main areas for consideration will be the transition areas on both sides of the Atlantic.

5.2 Main aspects requiring consideration

5.2.1 The Group agreed that the following main aspects required consideration :

5.2.1.1 Route structure

5.2.1.1.1 It appears that the wind and temperature fields over the Atlantic are such that a fixed track structure, geared ideally to the great circle route, might be acceptable as distinct from the subsonic track structure which varies according to atmospheric conditions. However, such an assumption would need careful examination.

5.2.1.1.2 According to the volume of traffic, a track struture should be applied, full consideration being given to the problem of opposite direction flow.

5.2.1.2 Lateral spacing of OAC tracks

5.2.1.2.1 Lateral separation should be determined in accordance with the method already derived by the group. However, initial values for Concorde operation will have to be based on judgement and what information can be gathered on navigational capability from Concorde prototype flying and en route proving flights. It may be noted that specifications for the navigation capability of the Concorde are geared to ensuring a capability of operating with a lateral spacing of 60NM for post 1975 SST traffic rates.

5.2.1.3 Vertical separation within the oceanic control areas

5.2.1.3.1 In order to permit cruise climb it is considered that vertical separation should not be applied. However, advantage could be taken of natural vertical separation as between inbound and outbound aircraft in certain areas in the design of route structure.

5.2.1.4 Longitudinal separation

5.2.1.4.1 Smaller longitudinal separations in terms of time may be feasible, but attention may have also to be paid to the capability of domestic ATC to feed aircraft into the OAC track structure at or close to these minimum time intervals. Relative position checking techniques or devices may need to be considered.

5.2.1.4 Cost

5.2.1.4.1 The effect of values of separation standards on the cost of deviations from optimum track ought to be assessed using the RAE model for various years corresponding to forecast flow rates. In this way target values of separation standards likely to be needed can be specified.

5.2.1.5 In transition

5.2.1.5.1 Some thought should be given to values of separation standards for application in transition areas both at supersonic and subsonic speeds in relation to:

a) radar separation
b) procedural and particularly vertical separation.

5.3 Procedures

5.3.1 Oceanic clearance

5.3.1.1 Although present methods may serve initially, or if supersonic flight is only permitted over sea, nevertheless consideration should be given to a possible requirement for oceanic clearance either before take-off or immediately after take-off. Such a requirement would have considerable implications on the communication requirements between Shanwick and Gander OAC's and their neighbouring ACC's. It would also tend to imply the provision of reserved slots within domestic airspace for trans-atlantic SST traffic.

5.3.2 ATS Systems Concept

5.3.2.1 In the initial years of operation a strategic system similar to that existing at present will be appropriate. As the traffic builds up smaller separation standards will be required to keep the cost of deviations from optimum track within bounds. It is estimated that surveillance systems will be viable on a cost/benefit basis in the late 70's. Even so, the basis of ATC would remain strategic, the surveillance system being employed to prevent the inducement of large tolerances rather than permit a free for all tactical system. Tactical use of the surveillance function might be feasible off the principal routes or in quiet hours, but a saturated flow of traffic does not lend itself to tactical control.

5.3.3 Interrelation with subsonic traffic

5.3.3.1 Apart from the special problem resulting from the mixing of subsonic with SST traffic in transition areas adjacent to the oceanic control areas, the Group will need to consider whether descent from cruising levels, due to radiation hazard from solar flares, or engine failure for example, has any implications on the present variable track structure of the subsonic air traffic.

5.4 Communications

5.4.1 Although immediate and highly reliable communications are vital approaching or leaving the OAC they are not of first order importance in mid Atlantic, viewed solely in terms of management of the traffic flow, with a strategic system of control utilising separation standards ensuring safe separation for the crossing. However, no one doubts that general safety considerations demand the best possible communications over the whole ocean and the subject needs to be discussed, in particular in relation to emergency procedures such as that already mentioned in respect of descent due to solar flare radiation hazards. Clearly in the long term any established case for surveillance would imply an associated considerable improvement in communications.

5.5 Air reporting

5.5.1 Air reporting en route will need to be reconsidered in relation to the speed of aircraft. It may be that the best solution will be to eliminate it altogether leaving channels free for communications as and when necessary.

5.6 Organization of airspace

5.6.1 Some questions of relative responsibility may arise between adjacent control centres, particularly as regards those areas where transition between the continental and the oceanic ATC system is effected.

5.7 Conclusion

5.7.1 The above provides only a broad review of the questions raised by SST operations. It is however believed that its main headings afford a basis for the determination of an agenda which no doubt will be subject to modifications and additions. It is however suggested that it would be wise to work through the agenda first in relation to initial operations in detail, and thereafter consider what needs to be set in train to ensure that longer term needs will be met.

x 6. Summary of Agenda Item 6 : Review of the future work programme of the Group

6.1 General review

6.1.1 When discussing this item, the Group agreed to use as a basis the work programme established at its 3. Meeting (para. 5.2.1 on page 5 - 2 of the Summary of the 3. Meeting refers). It was however also agreed that this list needed rationalisation of the individual items and the establishment of priorities with respect to each of the consolidated items since it was obvious that, with a rather large programme the Group was forced to be selective.

6.1.2 Before undertaking the rationalisation of the list, the Group felt it advisable to review the items listed by the 3. Meeting and make comments against each one of them in order to show the progress achieved to date as follows:

	Item	Comment
1)	Long Term Planning Programme	This is strictly part of the terms of reference but can be used to ensure co-ordination as work on individual items progresses.
* + 2)	Impact of SST Operations on the NAT Air Navigation System	Discussion should provide results for submission to the NAT RAN Meeting planned for 1970.
3)	Developments in Satellite	Initial discussions on project "ATS3" were held at the 3. Meeting. Probably major work on need and timescale in respect of NAT operations might be required.
4)	Improvement of logical Methods for the Determination of Separation Minima	The basis for work on this subject has been established. Refinements will be made later as necessary.

x This item was considered by members of the Group only.

	Item	Comment
5)	Future Planning for NAT Aeronautical Fixed and Mobile Services	Review of this item has so far not been considered urgent. It is however expected that major issues will arise from other studies, e.g. ADIS and ASTRA Panels.
6)	Provision of Ocean Stable Platforms	A possible system of providing surveillance.
7)	Future Planning for NAT Meteorological Services	The same comments as for 5) apply.
8)	Criteria for the Assessment of System Performance	Consideration was initiated at the 3. Meeting. Airline data is being collected for validation of a statistical traffic model. This appears to be a promising basis for long-term planning.
* 9)	Review of NAT Air Reporting Procedures	Treated at the 3. Meeting and action on short-term changes completed at this Meeting. Consideration of other items such as the NAT ATC procedures may lead to a more fundamental look at this subject.
+ 10)	Vertical Separation above Flight Level 290 in Specified Parts of the NAT Region	Method of derivation agreed. Further work continued by the Netherlands, U.S.A., United Kingdom and IFALPA in preparation for the next meeting of the Group and the NAT RAN Meeting planned for 1970.
* + 11)	Longitudinal Separation in Specified Parts of the NAT Region	Work on this subject continued at this meeting as reported under Agenda Item 4.

12)	Review of NAT ATC Procedures	Depends on development in other items. Would become a major item with fundamental changes to the support facilities, e.g. introduction of satellite surveillance, in connection with automation of ATC, and when composite separation standards will be considered.
13)	Consideration of up-dated Traffic Forecasts	Watching brief on activities of Forecasting Group.

Notes :

i) Items on which a substantial amount of work has already been done are underlined.

ii) Items included in the agenda of the 4. Meeting are marked by an asterisk *.

iii) Items included in the tentative agenda for the 5. Meeting of the Group in December 1968 are marked by a cross +.

6.2 Rationalisation of the list

6.2.1 It was noted that until this meeting nearly all the efforts of the Group had been devoted to solving the controversy in lateral separation. This had left little time for more than a perfunctory examination of the work programme. However it now appeared that more attention should be paid to this subject in order to make clear what could reasonably be expected from the Groups in the way of working efforts and results achieved.

6.2.2 It was believed that the work programme should be separated into two parts, one covering the long-term aspects and one for short-term items which would, at the same time, also provide an indication of the priorities afforded to the various items.

6.2.3 As regards the long-term work programme the Group agreed that this could be established in the following way:

Long Term Planning (1)

The yardstick for comparing systems and assessing needs (8) (13)

Possible Systems

i) Development of the present system based on improved navigation capability of aircraft (12) (5)

ii) Ocean Stable Platforms (6) (12) (5)

iii) Communication and Surveillance Satellites (3) (12) (5)

Separation Standards

(4) (10) (11)

6.2.4 As to the short-term programme it was agreed that this should cover the following:

i) Completion of work on present navigational capability and hence determination of separation standards including composite standards if practicable and necessary (11) (10) (12)

ii) Provisions for the periodic review of the navigational capability of aircraft (new item)

iii) Measures required for the introduction of SST into operation (2) (12)

iv) Air Reporting (7) (9) (12)

v) Problems in the transition areas (was already briefly discussed).

Note: The figures in brackets shown in this paragraph and in para. 6.2.3 refer to the item numbers shown in para. 6.1.2.

6.2.5 As previously stated it became obvious that the Group will have to be selective in its field of endeavour. Because of this, it was agreed that subjects involving a very high degree of specialization, such as the technical aspects of a satellite system, should be avoided and that the Group should confine its efforts to the definition of requirements and time-scales for system changes and the way in which such systems could be exploited. It would also endeavour to provide quantitative estimates of the benefits to operators of the various systems considered thus permitting comparative cost/benefit studies by interested parties.

6.2.6 When considering the next two year period, the Group believed that the subjects which needed study most urgently or which are ripe for development are the following:

Long Term. 1) The yardstick for comparing systems, i.e. (8) criteria for the assessment of system performance, and its application to comparative studies of possible systems.

Short Term. 2) Bring to a conclusion what separation standards can be adopted for the next few years in the light of the navigational capability determined to exist in the NAT Region. This would include further consideration of composite separation standards. This has been provided for in the tentative agenda of the 5. Meeting of the NAT/SPG later this year.

3) Introduction of SST and transition area problems.

6.2.7 Finally under the heading "long term" comparative overall cost/benefit studies of possible systems should include the consideration of satellite systems. The ICAO ASTRA Panel will no doubt define preferred technical systems and related system characteristics upon which Regional Planning could be based. By close coordination between this Panel and the Group the cost/benefit of systems can be determined. Technical progress will certainly be assisted if the Group can define the need and timescale for a surveillance system in more precise and convincing terms than are now available, or conversely state how long the present system can remain effective, based solely on the navigational capability of aircraft and taking into account progress that can be expected in this field.

6.3 Review of the working methods of the Group

6.3.1 In connection with the review of the work programme the Group also made a brief review of its working methods since it was believed that these had a significant influence on its proceedings and it had been found that there was still room for improvement.

6.3.2 A suggestion to create a limited number of specialized sub-groups to deal with specific subjects and report their findings to the Group was at this time not retained since it was felt that, apart from raising organizational and economic problems, this may create coordination problems which could be such as to offset any advantages gained by the creation of such groups. It was however agreed that the ad-hoc collaboration which had occasionally been established between interested parties in the past should by all means be continued and improved if this was found to be beneficial.

6.3.3 It was further agreed that there were two distincts fields in which improvements could be obtained. These are:

i) the more timely preparation of supporting documentation by members for the meetings of the Group and

ii) better preparations in general for the meetings.

With regard to i) it was suggested that, well in advance of meetings, members may wish to circulate even provisional editions of their documentation to all other members for comment and suggestions so that documents produced for the meeting represent some degree of agreement in principle. As to ii) it was hoped that the Administrations and Organizations concerned would find it possible to allow participants in meetings of the NAT/SPG to devote sufficient time to their preparation so that valuable time is not lost during the meeting with the familiarization of the subjects to be considered.

6.3.4 Finally it was agreed that, in view of past experience, it would be best if supporting documentation by members and other participants in meetings of the Group were not circulated individually by the originator but addressed to the Chairman with a copy to the Paris Regional Office of ICAO so that reproduction and circulation could be arranged in the most appropriate manner.

7. Summary of Agenda Item 7 : Any other business

7.1 General

7.1.1 Contrary to the provisions made in the agenda, the Group agreed that the points raised in this item should be considered in the presence of all participants in the meeting.

7.2 Review of the individual points raised

7.2.1 Provision of a VHF/air-ground communication station on the Faroe Islands

7.2.1.1 IATA informed the Group of the possibility of using an existing VHF air-ground communication station on the Faroe Islands as relay in order to allow the use of VHF in communication with the Oceanic Control Centre Reykjavik by aircraft operating on polar routes and those operating between Iceland and the European continent or between the U.S.A., Canada, Greenland and the Scandinavian area. The only technical means needed to enable this station to act as a VHF air-ground relay station was a direct telephone link with Reykjavik OAC and it was thought that the SCOTICE communication link could be used for this purpose. This proposal by IATA had been supported by Iceland prior to the meeting in a letter addressed to the Chairman of the Group.

7.2.1.2 Even though the Group realized that the early integration of such a facility would have beneficial effects on the air-ground communication situation in the area covered by the Station and thus also on the whole of the NAT Region, it was nevertheless believed that the proposal in question was a matter which had no planning aspects in the sense of the mandate of the Group while considering that there may be merit in the proposal, the Group felt that this was a matter which could be more appropriately dealt with through normal ICAO channels. It was therefore suggested that the States concerned (Denmark and Iceland) should take appropriate action.

7.2.2 Use of SSR in the NAT Region

7.2.2.1 It was noted that, following the completion of the data collection programme, during which SSR had been used to identify individual flights, the use of SSR had now been reduced again to the simple functional indication of the direction of flight.

7.2.2.2 The question was therefore raised by IFALPA whether it would not be possible to assign SSR codes in such a way as to provide an indication of the flight level at which the aircraft was operating.

7.2.2.3 In the ensuing discussion, it was pointed out that such a proposal was not yet feasible because of decoding equipment limitations on the ground (availability of single-channel passive decoding equipment only). It was therefore confirmed by the Group that the practice at present followed by IATA member airlines, whereby code A/2000 is used by all eastbound flights and code A/2100 by all westbound flights, should be extended until such time as improvements in the decoding equipment provided at ground stations permitted the adoption of a different and more sophisticated use of SSR.

7.2.3 <u>Criteria for the assessment of system performance</u>

7.2.3.1 When considering this subject at the 3. Meeting, airlines were asked to add, on the reverse of Form 1-D the coordinates of the track filed in the flight plan, the coordinates of what would have been the most desirable flight path and flight levels had the organized track system not existed, and relevant remarks. The U.K. member informed the Group that, even though this request had not been complied with in all cases, there was sufficient data to warrant the preparation of a report showing to what extent this information served to validate the RAE method previously discussed. As this might assist some future discussion of the subject, the report on this subject will be circulated shortly.

7.2.4 <u>Retention of flight records</u>

7.2.4.1 Operators had previously been advised that, if no request to the contrary was received by 30 June 1968, all flights records obtained by operators in the data collection programme could be destroyed. In discussion at this meeting it had however been found that these records could still be of considerable value and it had therefore been agreed that operators should be requested to retain them further.

7.2.4.2 In cooperation with representatives from IATA, Mr. Huard, the Coordinator of the data collection programme, had therefore arranged for notification of all IATA member airlines to retain their records until a further note regarding the disposition of them was received, this note to reach operators not later than by the end of July 1968.

7.2.4.3 It was realized that this arrangement did not cover those operators which were not members of IATA. However since the records of these operators constituted only a very small percentage of the total material available, it was felt that their destruction would not be of any significance and that they could therefore be neglected.

* 8. Summary of Agenda Item 8 : Election of the next Chairman

8.1 Mr. J.F. Sapin, the member from France was re-elected unanimously as chairman of the next meeting on a proposal by the Netherlands member, Mr. ten Velden, seconded by the U.S.A. member, Mr. Huard.

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* This item was considered by members of the Group only.

* 9. Arrangements for the next meeting

9.1 Date and site of the next meeting

9.1.1 The Group agreed that its next meeting should be held in late 1968 at ICAO Headquarters in Montreal. It noted with satisfaction that arrangements had already been made by the ICAO Secretariat to reserve the period from 2 to 14 December 1968 for this purpose and the Group agreed to these dates.

9.2 Tentative Agenda

9.2.1 After careful consideration of the future work programme (see Summary of Agenda Item 6) and taking due account of priorities imposed by likely developments, the Group agreed that, subject to confirmation at a later date, the tentative agenda for the next meeting should comprise the following principal items:

i) determination of preparatory ATS measures required for the start of SST operations in the NAT Region;

ii) review of developments regarding the application of reduced vertical separation to aircraft operating above FL 290 in the NAT Region;

iii) review of the possibility to apply "composite separation" (i.e. a form of separation composed of the simultaneous application of reduced minima of lateral and vertical separation) to aircraft operating in the NAT Region;

iv) review of progress made in the assessment of longitudinal separation in certain parts of the Region, including the possible use of DME for the maintenance of such separation;

v) review of the criteria for the assessment of system performance (if time permits).

9.3 Attendance

9.3.1 In view of the tentative agenda, the Group agreed that Portugal and Iceland, as well as IANC, IATA and IFALPA should again be invited to participate in the next meeting of the Group.

9.4 Meeting arrangements

9.4.1 The Group hoped that the decision to hold the next meeting of the Group at ICAO Headquarters in Montreal will imply that the meeting arrangements there will correspond to those made for this meeting.

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* This item was considered by members of the Group only.

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LIST OF REFERENCE-DOCUMENTS RELATING TO SEPARATION

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