COPY 1

FAA WJH Technical Center
00092532

NAFEC TECHNICAL LETTER REPORT

NA-79-2-LR

NA-79-2-LR

CONSIDERATION OF THE MNPS AND THE IMPLEMENTATION OF 90-NMI COMPOSITE SEPARATION IN THE NAT REGION

by Allen C. Busch

PROJECT NO. 012-102-210

January 1979

FEDERAL AVIATION ADMINISTRATION
NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
Atlantic City, New Jersey 08405

NOTICE

This document is disseminated to provide for quick reaction release of technical information to selected users. The contents may not conform to FAA formal publication standards and the technical information is subject to change and/or incorporation into a formal publication at a later date.

Approved by for Thomas J. O'Brien

JOSEPH M. DEL BALZO
Acting Director, National Aviation Facilities
Experimental Center
Federal Aviation Administration
Department of Transportation

TABLE OF CONTENTS

	Page
Abstract	1
1.0 Introduction	1
2.0 Discussion	1
3.0 Conclusion	6
Appendix A	7
Appendix B	13
Acknowledgment	12
Distribution	13

CONSIDERATION OF THE MNPS AND THE IMPLEMENTATION OF 90-NMI COMPOSITE SEPARATION IN THE NAT REGION

Allen C. Busch

DOT/FAA's National Aviation Facilities Experimental Center

ABSTRACT

Data from the first seven months of 1978 taken in the North Atlantic Organized Track System (NAT/OTS) was examined for the consideration of implementing a 90-nmi composite route structure. The data was examined for compliance with both the eta (frequency of deviation equal to or greater than half a lateral separation and the zeta (frequency of deviation between ± 10-nmi of the separation standard) requirements. When compared with the sequential testing techniques, it was found that the data would support the implementation of a 90-nmi composite structure.

1.0 INTRODUCTION

At a special meeting of the ICAO North Atlantic Systems Planning Group meeting held in London, England on July 31 to August 8, 1978, it was concluded that the navigational performance observed during the first seven months of 1978 did not justify the reduction in lateral separation between aircraft from 120 to 60 nautical miles. It was the consensus of the meeting that a further period of data collection and subsequent evaluation, "at least extending to December 31, 1978, would be desirable in order to determine whether an improvement in the quality of performance had been achieved towards a separation reduction."

The meeting decided that the new data would be considered at the 15th meeting of the NATSPG in February 1979 to determine if the lateral navigational performance would be adequate to permit a decision to implement a reduced lateral separation.

This working paper is an analysis of the data presented at the special meeting to determine if a reduction in lateral separation could be justified. The particular scheme analyzed here is a 90-nmi composite route structure where each laterally adjacent route is separated by 45-nmi laterally and 1000 feet in altitude.

2.0 DISCUSSION

In the analysis performed for this study it was assumed that the numerical values derived from the MNPS methodology for a 60-nmi separation would be a conservative estimate of a 90-nmi composite

separation structures, i.e.:

(a) the standard deviation of lateral track errors shall be less than 6.3-nmi;

(b) the proportion of the total flight time spent by aircraft one-half separation standard ($S_y/2$, in this case 45-nmi) or more off track shall be less than 5.3×10^{-4};

(c) the proportion of the total flight time spent by aircraft $\pm$ 10-nmi around the separation standard (S_y, in this case between 80 and 100-nmi off track shall be less than 1.3×10^{-4}.

Again the most significant parts of this requirement stated in terms of the monitoring are:

(1) the frequency of all deviations, observed at the end points of the oceanic track structure, that are greater than over half a separation standard (refered to as the eta, η requirement)

(2) the frequency of all deviations between $\pm$ 10-nmi of the separation standard (refered to as the zeta, ζ requirement).

Two considerations dominate the proposal to consider a 90-nmi composite lateral separation route structure: (1) it provides for a considerably lower level of risk than would a 60-nmi lateral structure and therefore an increased probability that the present lateral deviation data would be acceptable in light of the MNPS requirements, (2) it provides for more routes in a smaller volume of air space and thus a smaller fuel cost penalty in that the routes would more closely approximate the minimum great circle route between the North American Continent and U.K./European Continent. Six routes separated by 60-nmi laterally would occupy 300-nmi lateral air space whereas six routes using a 90-nmi composite structure would only occupy 225-nmi lateral air space. There would however be three fewer flight paths in the 90-nmi composite structure, in that for example, routes 1, 3 and 5 would have seven altitudes available (flight levels 290, 310, 330, 350, 370, 390, and 410) and routes 2, 4 and 6 would have only six altitudes available (flight levels 300, 320, 340, 360, 380 and 400). Whereas in the 60-nmi structure all six routes would have flight levels 290, 310, 330, 350, 370, 390 and 410 available. This does not seem to be at all significant in that the aircraft flight preference data suggests that very few aircraft desire to fly at the lower altitudes or at the maximum altitude of 410.

An assumption in this analysis is that the lateral occupancies for the composite structure would be the same as or less than estimated occupancies for the 60-nmi lateral structure. This does not seem to be an unwarranted or irrational assumption in that the calculation of occupancies is so uncertain and in that there should be a requirement to monitor occupancies during the first six months after a new system structure is implemented to determine just what aircraft flight path preferences are manifested. Also as a general rule if you have six routes that are all laterally adjacent one from another and you take every route and offset it in altitude (which is what composite does) you have now only two sets of three routes which are laterally adjacent and thus overall lateral occupancy should be expected to be somewhat less.

Given the acceptance of these assumptions, the collision risk parameter estimates and the derived values from the MNPS are as given for the 60 -nmi proposal. Since in each case the estimates for the 90-nmi composite appear to be conservative it might be desirable to derive the specific estimates applicable to this 90-nmi composite proposal at some later date if operational implementation appears desirable. The only problem remaining is to assess the data obtained from the NAT/OTS to see if the data supports the adoption of an MNPS 90-nmi composite route structure.

The two critical parameters to be examined are the eta and zeta requirements. The data from the January 1978 through July 1978 for deviations equal to or greater than 30-nmi is rather sparse, i.e. 23 observations out of a total traffic count of 33,399 aircraft movements observed, see Table 1 (taken from Appendix A of the Summary of the Special Meeting of the ICAO North Atlantic System Planning Group held in London, England on July 31 - August 8, 1978). Because of the sparseness of the data the expectation of finding an observation at any one point in space is very small. Thus it was felt that the best analytical approach would be to fit the data with a double double exponential distribution, derive the least squares best estimate of the parameters of the distribution and then estimate the expected values of eta and zeta. Then if the estimated values of eta and zeta from the real data were not significantly contradicted by the observed values of the real data, compare the estimates with the derived values of the MNPS requirements for the 90-nmi composite structures.

The data provided in Appendix B of the NAT/SPS summary was used for fitting the core, i.e. the Shannon and Stornaway radar data was used to represent the core data and the data in Table 1 was used to represent

TABLE 1

List of All Deviations Considered in the Mathematical Analysis

Date		FL	Estimate of Deviation	Number ≥ 45-nmi	Number Between 80 & 100-nmi and multiples thereof	Traffic Movements
Jan	8	380	55	1		921
	14	330	40			1612
	14	310	46	1		1612
	24	350	47	1		2764
Mar	2	330	30			7478
	17	350	180	1	1	9415
	26	350	50	1		10577
	30	370	60	1		11094
Apr	15	300	55	1		13409
	19	290	120	1		13992
	21	330	60	1		14203
	23	310	40			14575
May	13	370	60	1		17857
	14	370	55	1		18031
	15	340	100	1	1	18205
	19	370	38			18900
	20	290	130	1		19074
June	7	370	40			22528
	8	380	30			22748
	17	340	70	1		24728
July	11	350	60	1		26950
	25	370	30			32274
	29	370	38			33024
TOTALS				15	2	33399

the tail data. Since the number of flights in the radar data was only 944 (544 from Shannon and 400 from Stornaway) and the number of flights used for estimating the gross errors was 33,399 the radar data was first fitted, the least squares best estimates of the data were calculated, and then it was assumed that this would be the best estimate of the data if all 33,399 observations were the same as the limited set utilized. Also since the gross errors were without sign (that is no designation as to being right or left of course) the data was folded over zero even though some small bias, that is a non zero mean was observed in the data. The character of the core data is presented in the Appendix. Even though there were some differences in both the mean and standard deviations of the Shannon and Stornaway radar data, it is believed that the differences are not due to the response variable, that is the true lateral deviation of aircraft from track but due to the measurement variable, that is differences in the two radar systems. Thus the weighted sum of the two distributions was used and the parameter estimates made for the sum of two exponential distributions (sometimes referred to as a double double exponential). See Appendix for the appropriate tables. From the fitted distribution the probability of being equal to or greater than 45-nmi was estimated and the probability of being between 80 and 100-nmi were estimated thus:

(1) probability $\geqslant$ 45-nmi = 3.29×10^{-4}

(2) probability of being between 80 and 110-nmi = 5.3×10^{-5}

(3) σ (of core) = 4.3-nmi

Given that the above estimates are valid then the question to be answered is how do they compare with the MNPS requirements and the acceptance criteria. The established eta (η) and zeta (ζ) requirements are:

$\eta = 5.3 \times 10^{-4}$

$\zeta = 1.3 \times 10^{-4}$

A comparison of the requirements with the estimates from the data indicates the data estimates to be less than the requirement using the sequential testing procedure accepted at the special NAT/SPG meeting also indicates the data falls within the "Accept Region" on the charts. One further question might be asked and that is if you don't believe that the use of the fitted data is the best estimator but choose to use the real data what does the situation look like.

From Table 1 the estimate of the probability of being equal to or greater than 45-nmi is 4.5×10^{-4} and the probability of being between 80 and 100-nmi is 5.99×10^{-5}. These values are larger than that from the fitted data but still smaller than the MNPS requirements. Also this data falls within the "Accept Region" of the sequential testing.

3.0 CONCLUSION

The previous analysis indicates that the seven months of data from monitoring the North Atlantic Organized Track System would support the requirements for reducing the route structure to a 90-nmi composite route system. The comparing of the eta (η) and zeta (ζ) requirements from the MNPS methodology with the fitted estimates of the data and the observed data shows that the requirements are met and fall within the acceptance region of the sequential testing criteria.

Since the sequential testing of observed data resulted in acceptance, one can conclude with at least 95% confidence that navigation performance in the NAT is in compliance with the MNPS η & ζ requirements.

In actuality the derived navigational system requirements for a 90-nmi composite zeta given the previous assumption of equal occupancies, etc., the expected values of zeta would be approximately the same. The expected value of eta would be larger and the expected value of sigma could be larger. Thus since the data clearly supports analytically going to a 90-nmi composite separation with the comparison presented here, any relaxing of the eta, zeta, or sigma requirements would make the acceptance even easier.

APPENDIX A

TABLE A-1

Shannon Radar Data

Freq. Class	% of Sample	Freq.
0 - .6	12.925	70.31
.6 - 1.2	14.12	76.84
1.2 - 1.8	12.68	68.95
1.8 - 2.4	10.28	55.90
2.4 - 3.0	8.10	44.06
3.0 - 3.6	6.88	37.40
3.6 - 4.2	6.70	36.45
4.2 - 4.8	6.52	35.50
4.8 - 5.4	5.08	27.61
5.4 - 6.0	4.35	23.66
6.0 - 6.6	3.85	20.94
6.6 - 7.2	2.40	13.06
7.2 - 7.8	1.42	7.75
7.8 - 8.4	1.25	6.80
8.4 - 9.0	0.88	4.76
9.0 - 9.6	0.68	3.67
9.6 - 10.2	0.48	2.58
10.2 - 10.8	0.22	1.22

FAA WJH Technical Center
00092532

TABLE A-2

Shannon Radar (adjusted) and Gross Lateral Errors

Mid point of freq. class	Frequency	Cumulative
0.3	4366.2	0.13073
0.9	4771.6	0.27360
1.5	4281.8	0.40180
2.1	3471.0	0.50572
2.7	2736.3	0.58765
3.3	2322.5	0.65729
3.9	2263.4	0.72496
4.5	2204.2	0.79095
5.1	1714.4	0.84228
5.7	1469.5	0.88628
6.3	1300.6	0.92522
6.9	810.7	0.94950
7.5	481.4	0.96391
8.1	422.3	0.97655
8.7	295.6	0.98540
9.3	228.0	0.99223
9.9	160.5	0.99704
10.5	76.0	0.99931
13.8	0.0	0.99931
19.8	0.0	0.99931
25.8	0.0	0.99931
31.8	3.0	0.99940
37.8	5.0	0.99955
43.8	1.0	0.99958
49.8	2.0	0.99964
55.8	3.0	0.99973
61.8	4.0	0.99985
67.8	1.0	0.99988
73.8	0.0	0.99988
79.8	0.0	0.99988
85.8	0.0	0.99988
91.8	0.0	0.99988
97.8	0.0	0.99991
103.8	0.0	0.99991
109.8	0.0	0.99991
115.8	0.0	0.99991
121.8	1.0	0.99994
127.8	1.0	0.99997
⋮	⋮	⋮
181.8	1.0	0.99999

Total Number of Observations = 33399.0

Sum of two exponential distributions

$\lambda_1 = 2.942$

$\lambda_2 = 53.628$

$\alpha = 0.99922$

TABLE A-3

Stornaway Radar Data

Frequency Class	% of Sample	Frequency
0 - 1.0	21.45	83.0
1.0 - 2.0	19.90	77.0
2.0 - 3.0	16.15	62.5
3.0 - 4.0	11.37	44.0
4.0 - 5.0	8.14	31.5
5.0 - 6.0	7.24	28.0
6.0 - 7.0	5.94	23.0
7.0 - 8.0	4.65	18.0
8.0 - 9.0	2.97	11.5
9.0 - 10.0	1.55	6.0
10.0 - 11.0	0.65	2.5

T4

Stornaway Radar (adjusted) and Gross Lateral Errors

Midpoint of freq. class	Frequency	Cumulative
0.5	7158.2	0.21432
1.5	6640.7	0.41315
2.5	5390.2	0.57454
3.5	3794.7	0.68816
4.5	2716.6	0.76950
5.5	2414.8	0.84180
6.5	1983.6	0.90119
7.5	1552.4	0.94767
8.5	991.8	0.97737
9.5	577.4	0.99286
10.5	215.6	0.99931
13.5	0.0	0.99931
18.5	0.0	0.99931
23.5	0.0	0.99931
28.5	3.0	0.99940
33.5	0.0	0.99940
38.5	5.0	0.99955
43.5	1.0	0.99958
48.5	2.0	0.99964
53.5	3.0	0.99973
58.5	4.0	0.99985
63.5	0.0	0.99985
68.5	1.0	0.99980
73.5	0.0	0.99988
78.5	0.0	0.99988
83.5	0.0	0.99988
88.5	0.0	0.99988
93.5	0.0	0.99988
98.5	1.0	0.99991
⋮	⋮	⋮
118.5	1.0	0.99994
123.5	0.0	0.99994
128.5	1.0	0.99997
⋮	⋮	⋮
178.5	1.0	1.0000

Total number of observations = 33399

Sum of two exponentials $\lambda_1 = 3.177$

$\lambda_2 = 53.974$

$\alpha = 0.99927$

TABLE A-5

Shannon and Stornaway Combined

Sum of two exponential distributions:

Combined distribution (Shannon & Stornaway)

$$\lambda_1 = \frac{537.44\,\lambda_{11} + 387.0\,\lambda_{12}}{537.44 + 387.0} = 3.0403$$

$$\lambda_2 = \frac{537.44\,\lambda_{21} + 387.0\,\lambda_{22}}{537.44 + 387.0} = 53.77$$

$$\alpha = \frac{537.44\,\alpha_1 + 387.0\,\alpha_2}{537.44 + 387.0} = 0.99924$$

ACKNOWLEDGMENTS

Doctor J. S. Hunter of Princeton University under contract DOT/FA-72-NA-741 contributed significantly to the technical and numerical computations for the preparation of this report.

The work discussed in this report was conducted under NAFEC Program Document 01-203, FAA Subprogram 012-102. The program manager was Brian Colamosca, who can be contacted for further information.

APPENDIX B

NA-79-2-LR

Distribution:

AED-1
AEM-1
AEM-11 (H. Libby)
AEM-100 (25 copies)
ANA-1
ANA-2 (2 copies)
ANA-4
ANA-5
ANA-64 (3 copies)
ANA-100
ANA-200
ANA-300
ANA-400
ANA-500
ANA-523
ANA-600
ANA-700
ARD-1