



International Civil Aviation Organization

**The Twentieth Meeting of the Regional Airspace Safety Monitoring
Advisory Group (RASMAG/20)**

Bangkok, Thailand, 26-29 May 2015

Agenda Item 4: Airspace Safety Monitoring Documentation and Regional Guidance Mater

DEVELOPMENT OF GLOBAL ICAO MANUAL ON PBHSM

(Presented by Australia and the USA)

SUMMARY

This paper provides details on the development of global guidance material for the monitoring of performance-based horizontal separation. The draft manual has been developed by the ICAO SASP over a number of years and is a globalization of the Asia/Pacific Enroute Monitoring Agency Manual.

1. INTRODUCTION

1.1 This working paper contains advance information on the new Manual on Monitoring the Application of Performance-Based Horizontal Separation Minima (PBHSM) proposed by the SASP as global guidance. The work is directly based on the current Asia/Pacific Enroute Monitoring Agency Handbook.

2. DISCUSSION

2.1 Project Team 17 (PT 17) of the SASP has been working to develop a draft of the Manual on Monitoring the Application of Performance-Based Horizontal Separation Minima. The SASP recognised the value of the material in a performance based and proactive Safety Management (SM) environment. In that environment, the monitoring of safety performance, events analysis and obtaining intelligence, drawn from data collection and processing is critical.

2.2 The new guidance material aims to share experiences, methodologies and processes to those Regions and or groups of States who currently do not have formalized monitoring facilities such as those provided by other regional monitoring organizations, but require such a facility to be established. The guidance material, set-out in a formal ICAO Document (see **Attachment A**) will provide opportunities for global standardization of approach and enables data and intelligence sharing across the globe to avoid any localized or unique safety management and risk assessment processes. Identification of common risks, currently based on a small set of event data, can also be enhanced from providing access to a standardized and wider data set facilitated by compatible monitoring operations.

2.3 The attachment to this paper contains the final version which will shortly be coordinated by the ICAO HQ Secretariat to interested groups for review.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

- a) Note and discuss the draft document provided at **Attachment A**.

.....

Doc [PBHSM] (DRAFT)



DRAFT

Manual on Monitoring the Application of Performance- based Horizontal Separation Minima

SASP/26 agreed that this draft version is ready for regional and Secretariat review.

Version 8.4 — 14 May 2015

International Civil Aviation Organization



DRAFT

Manual on Monitoring the Application of Performance- based Horizontal Separation Minima

SASP/26 agreed that this draft version is ready for regional and Secretariat review.

Version 8.4 — 14 May 2015

International Civil Aviation Organization

Published in separate Arabic, Chinese, English, French, Russian and Spanish editions by the
INTERNATIONAL CIVIL AVIATION ORGANIZATION
999 Boulevard Robert-Bourassa, Montréal, Quebec, Canada H3C 5H7

For ordering information and for a complete listing of sales agents and booksellers, please go to the ICAO website at www.icao.int.

Version 8.4 — 14 May 2015

ICAO Doc [PBHSM], Manual on Monitoring the Application of Performance-Based Horizontal
Separation Minima
Order Number: Doc[PBHSM]
ISBN [TBD]

© ICAO 2015

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means, without prior permission in writing from the International Civil Aviation Organization.

Amendments are announced in the supplements to the Catalogue of ICAO Publications; the Catalogue and its supplements are available on the ICAO website at www.icao.int. The space below is provided to keep a record of such amendments.

[illegible]

Table of Contents

	<i>Page</i>
FOREWORD	xi
Chapter 1. Definitions.....	1-1
1.1 Terms and definitions	1-1
1.2 Acronyms.....	1-7
Chapter 2. DESCRIPTION OF THE FUNCTIONS NECESSARY TO MONITOR THE APPLICATION OF PERFORMANCE-BASED HORIZONTAL SEPARATION MINIMA.....	2-1
2.1 Description.....	2-1
2.2 Duties and Responsibilities for Monitoring the Application of Performance-based Horizontal Separation Minima	2-1
2.3 Process for establishing the functions necessary to monitor the application of performance-based horizontal separation minima	2-2
Chapter 3. RESPONSIBILITIES AND STANDARDIZED PRACTICES	3-1
3.1 Purpose of this chapter.....	3-1
3.2 Establishing the Competence Necessary to Conduct a Safety Assessment in a Region.....	3-3
3.3 Responsibilities and Standardized Practices for the Pre-Implementation Phase	3-3
3.3.1 Review of Operational Concept.....	3-3
3.3.2 Steps for Conducting a Pre-Implementation Safety Assessment.....	3-3
3.4 Responsibilities and Standardized Practices for Both Pre-Implementation and Post-Implementation Phases	3-6
3.4.1 Establishment and Maintenance of Database of Performance Based Operation Approvals.....	3-6
3.4.2 Monitoring of Operator Compliance with State Approval Requirements	3-7
3.4.3 Monitoring of Communication, Navigation, and Surveillance Performance	3-9
3.4.3.1 General.....	3-9
3.4.3.2 Monitoring Core Navigational Performance.....	3-9
3.4.3.3 Monitoring Longitudinal Performance – Speed Variation.....	3-9
3.4.3.4 Monitoring of Large Lateral Deviations (LLDs) and Large Longitudinal Errors (LLEs)	3-10
3.4.3.5 Communication and Surveillance Performance Monitoring.....	3-11
3.4.4 Conducting Safety Assessments and Reporting Results.....	3-12
3.4.4.1 Assembling a Sample of Traffic Movements from the Airspace.....	3-12
3.4.4.2 Safety Assessment	3-13
3.4.4.3 Determining Whether the Safety Assessment Satisfies the TLS	3-13
3.4.4.4 Remedial Actions.....	3-14

List of Figures

Figure 3-1.	Pre/post-implementation horizontal separation minima flow chart.....	3-2
Figure 3-2.	Monitoring of operator compliance with State approval requirements flow chart.....	3-8

List of Tables

Table 3-1.	Steps for conducting a safety assessment	3-4
------------	--	-----

Appendices

Appendix A	MANAGING PERFORMANCE-BASED OPERATIONAL APPROVALS	1
A.1	Forms for use in obtaining records of performance-based operational approvals from a State authority	1
A.1.1	General - forms	1
A.1.2	Point of Contact Details for Matters Relating to State Performance-Based Operational Approvals.....	3
A.1.3	Record of State Performance-Based Operation Approval	4
A.1.4	Withdrawal of State Performance-Based Operation Approval.....	6
A.1.5	Letter to State authority requesting clarification of the state performance based operation approval status of an operator.....	7
A.2	Minimal informational content for each state performance-based operation approval to be maintained in electronic form	8
A.2.1	Aircraft Performance Based Operation Approvals Data	8
A.2.2	Aircraft Re-Registration/Operating Status Change Data.....	10
A.2.3	Point of Contact Data	11
A.2.4	Data Exchange among monitoring organizations	12
A.2.4.1	General.....	12
A.2.4.2	Data Exchange Procedures.....	12
A.2.4.3	Exchange of Aircraft Approvals Data.....	13
A.2.4.4	Aircraft Re-Registration/Operating Status Change Data	14
A.2.4.5	Exchange of Contact Data.....	14
A.2.4.6	Confirmed Non-Compliant Information	16
A.2.4.7	Fixed parameters -Reference Data Sources	16
Appendix B	FORM FOR ATS UNIT MONTHLY REPORT OF LLD OR LLE.....	1
Appendix C	SCRUTINY GROUP GUIDANCE	1
C.1	Composition.....	1
C.2	Purpose	1
C.3	Process	1
C.4	Analysis and Methodology	2

Appendix D	TRAFFIC SAMPLE DATA (TSD) FOR TRAFFIC MOVEMENTS.....	1
Appendix E	EXAMPLE “KNOW YOUR AIRSPACE” ANALYSIS	1
E.1	Introduction	1
E.2	Background.....	1
E.3	Characteristics of L642 and M771	1
E.3.1	Operator Profile	1
E.3.2	Origin-Destination Aerodromes	3
E.3.3	Use of the RNAV Routes	4
E.3.4	Flight-Level Usage on L642 and M771.....	5
E.3.5	Operator/Aircraft-Type Combinations	5
E.4	Summary.....	6
Appendix F	OVERVIEW OF PERFORMANCE BASED HORIZONTAL COLLISION RISK MODELLING ASSUMPTIONS.....	1
F.1	Longitudinal Collision Risk Model	1
F.1.1	General.....	1
F.1.2	Controller intervention buffer.....	2
F.1.2.1	ATC to pilot communication times.....	2
F.1.2.2	Controller intervention buffer scenarios	3
F.1.3	Navigation performance	5
F.1.4	Variation in aircraft speed	5
F.2	Lateral collision risk model	6
F.2.1	General.....	6
F.2.2	Lateral path keeping performance, $P_y(S_y)$	7
F.2.3	Average absolute relative along-track speed of two aircraft, $ \dot{x} $	7
F.2.4	Average absolute relative cross-track speed between aircraft pairs operating on tracks nominally separated by $S_y - \dot{y}(S_y) $	8
F.2.5	Same and opposite direction lateral occupancy – $E_y(\text{same})$ and $E_y(\text{opp})$	8
Appendix G	EXAMPLE SAFETY ASSESSMENT - SOUTH CHINA SEA COLLISION RISK MODEL AND SAFETY ASSESSMENT.....	1
G.1	Introduction	1
G.2	Background.....	1
G.3	Results of Data Collection	3
G.4	Risk Assessment and Safety Oversight – compliance with TLS values.....	5
G.5	Safety Assessment	8
G.5.1	General.....	8
G.5.2	Alternate Longitudinal risk assessment using Hsu Model.....	9
G.5.3	Assumptions	10
Appendix H	EXAMPLE SAFETY ASSESSMENT – HORIZONTAL SEPARATION REDUCTION IN NEW YORK OCEANIC AIRSPACE.....	1
H.1	Introduction	1
H.2	Background.....	1

H.3	Description of New York Oceanic Airspace	2
H.4	Operators and Aircraft Types Eligible for the Reduced Horizontal Separation Minima.....	3
H.5	Safety Assessment Methodology.....	5
H.5.1	General.....	5
H.5.2	Lateral Collision Risk Model.....	5
H.5.3	Longitudinal Risk Model.....	6
H.6	Data Sources Used for the Safety Assessment	10
H.6.1	General.....	10
H.6.2	Safety Databases.....	10
H.6.3	Ocean21 Archived Data.....	10
H.7	Examination of Proximate Aircraft Operations in New York Oceanic Airspace	10
H.8	Analysis of Data Retrieved from Safety Databases	13
H.9	Aircraft Lateral Deviations	14
H.10	Weather Deviations	16
H.11	Data Link Communication Performance	19
H.11.1	General.....	19
H.11.2	Data link time and continuity	20
H.11.3	Reported Data Link Outages	24
H.11.4	Overdue ADS Periodic Reports.....	26
H.12	Ocean21 Decision-Support Features Important to the Application of the Reduced Horizontal Separation Standards	27
H.13	Parameters for the Collision Risk Models	28
H.13.1	General.....	28
H.13.2	Parameters Common to the Lateral and Longitudinal Collision Risk Models	28
H.13.2.1	Aircraft length, wingspan and height - λ_x , λ_y and λ_z	28
H.13.2.2	Probability That Two Aircraft Assigned to the Same Flight Level Are in Vertical Overlap: $P_z(0)$	29
H.13.2.3	The Average Relative Vertical Speed of Two Aircraft Assigned to the Same Flight Level: $\overline{ \dot{z} }$	29
H.13.3	Parameters Used Only in Estimation of Lateral Risk.....	30
H.13.3.1	Average absolute relative along-track speed of two-aircraft as they pass on parallel tracks - $\overline{ \dot{x} }$	30
H.13.3.2	Average absolute relative cross-track speed between aircraft pairs operating on tracks nominally separated by S_y - $\overline{ \dot{y}(S_y) }$	30
H.13.3.3	Same- and Opposite-Direction Lateral Occupancies – $E_y(\text{same})$ and $E_y(\text{opp})$	30
H.13.3.4	Probability That Two Aircraft Lose Planned 30-NM Lateral Separation – $P_y(30)$	31
H.13.4	Parameters Used Only in Estimation of Longitudinal Risk.....	33
H.13.4.1	Assumed average ground speed of aircraft 1, V_1 , and aircraft 2, V_2	33
H.13.4.2	Average aircraft wingspan or length - λ_{xy}	33
H.13.4.3	Scale parameter for the speed error distribution - λ_v	33
H.13.4.4	ADS-C report interval - T	33
H.13.4.5	Controller intervention buffer - τ	34
H.13.4.6	Cross-track and along-track position error distributions.....	34

H.13.4.7	Number of aircraft pairs per hour, NP	35
H.13.4.8	Table of longitudinal collision risk parameters.....	35
H.14	Estimation of Lateral Risk and Comparison to the TLS.....	36
H.15	Estimation of Longitudinal Risk and Comparison to the TLS	36

FOREWORD.

1. Historical background

1.1 The International Civil Aviation Organization (ICAO) noted that some States and Regions either had implemented or planned to implement horizontal separation minima in procedurally controlled airspace based on published performance based operations requirements. It was also noted that these States and Regions had developed procedures and practices to support the ongoing safety of these implementations.

1.2 The 2011 publication of the First Edition of ICAO Doc 9937 – *Operating Procedures and Practices for Regional Monitoring Agencies in Relation to the Use of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive* – provides guidance about establishing such procedures and practices to support ongoing safe use of the Reduced Vertical Separation Minimum (RVSM). It was noted that there was no comparable ICAO-provided guidance for monitoring the application of performance-based horizontal separation minima. Accordingly, the ICAO Separation and Airspace Safety Panel (SASP) set about developing a manual analogous to Doc 9937 as a means of assisting States and Regions to standardize monitoring activities supporting performance based horizontal separation minima.

1.3 This document is the result of the SASP work, and should be considered to be supporting material to ICAO Doc 9859 - *Safety Management Manual*. The proactive safety performance monitoring and measurement guidance provided in this document can satisfy safety assurance requirements provided in ICAO Annex 19 – *Safety Management*. In developing the material contained herein, the SASP relied upon the experience of experts from its member States which had prior experience in developing relevant procedures and practices. In addition, Australia, New Zealand, Singapore and the United States contributed to this document, modified portions of the “Asia/Pacific Region En-Route Monitoring Agency (EMA) Handbook,” which these States had authored. Contributions by other regions, agencies and organizations are anticipated as the document matures and experience is gained.

2. Scope and purpose

2.1 The *Manual on Monitoring the Application of Performance-Based Horizontal Separation Minima* provides guidance and information to facilitate uniform application of Standards and Recommended Practices (SARPs) contained in Annex 6 — *Aircraft Operations*, Annex 8 — *Airworthiness of Aircraft*, Annex 11 — *Air Traffic Services*, Annex 19 — *Safety Management*, the provisions in the *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444) and, when necessary, the *Regional Supplementary Procedures* (Doc 7030).

2.2 This document is intended to assist groups of States or Regions in describing the functionality needed to monitor the safe application of performance-based horizontal separation minima in procedurally controlled airspace. The procedures for these separation minima apply performance-based navigation performance (PBN) contained in Doc 9613, and performance-based communication and surveillance (PBCS) contained in Doc 9869.

2.3 The tasks as described in this manual for monitoring the application of performance-based horizontal separation minima may refer to system performance monitoring functions described in ICAO Doc 9869 – *Performance-Based Communication and Surveillance (PBCS) Manual*.

2.4 States may also call on the expertise developed for monitoring the application of performance-based horizontal separation minima, to assist in the implementation of new horizontal separation minima. Such an approach, in conjunction with performance-based specifications, such as for area navigation (RNAV), required navigation performance (RNP), required communication performance (RCP) and required surveillance performance (RSP), would assist in globally harmonizing the implementation and application of horizontal separation minima.

2.5 This document applies to groups of States or Regions applying performance-based horizontal separation minima in an en-route environment where procedural separation minima are being applied. It is not intended for operations in terminal airspace or en-route environments where ATS surveillance services are provided should obtain safety-assessment and monitoring guidance elsewhere.

2.6 This manual is organized as follows:

- a) Chapter 1 provides provides terms, definitions and acronyms;
- b) Chapter 2 describes the functions necessary to monitor the application of performance-based horizontal separation minima by means of a list of duties and responsibilities;
- c) Chapter 3 provides specific guidance on the duties and responsibilities that support implementation of performance-based horizontal separation minima;
- d) Appendix A provides guidance on managing the status of performance-based operational approvals, and includes forms for collecting information, maintaining the information in electronic form and seeking clarification on operational approval status of an Operator;
- e) Appendix B provides a form for an ATS unit to provide a monthly report of large lateral deviations (LLDs) and large longitudinal errors (LLEs);
- f) Appendix C provides guidance for examining LLDs and LLEs;
- g) Appendix D provides the traffic sample data (TSD) to collect and use to characterize the airspace and traffic movements;
- h) Appendix E provides an example of an analysis that characterizes the airspace and traffic movements to support monitoring the application of performance-based horizontal separation minima;
- i) Appendix F provides and overview of collision risk modeling assumptions when assessing the application of performance-based horizontal separation minima; and
- j) Appendix G and Appendix H provide example safety assessments for the application of performance-based horizontal separation minima.

2.7 This document does not specify how the monitoring functions for applying performance based horizontal separation minima are implemented by a group of States or Region. The functions performed may be contained within a single organization or may be assigned to different working groups within the region. It is nevertheless recommended that the organization providing monitoring functions reports directly to a regional safety oversight group which is charged with monitoring overall system performance in light of regional safety goals. In turn, this safety oversight group reports either to the authorized planning and implementation regional group (PIRG) or the regional airspace safety group (RASG). For example, in the North Atlantic Region, the NAT Central Monitoring Agency (CMA) reports to the NAT Safety Oversight Group (SOG), which is authorized by the NAT Systems Planning Group (SPG). In the Asia/Pacific, several EMAs report to the Asia/Pacific Regional Airspace Safety Monitoring Advisory Group (RASMAG), which reports to the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG).

3. References

ICAO documents

Annex 6 — *Operation of Aircraft*

- *Part I* — International Commercial Air Transport — Aeroplanes
- *Part II* — International General Aviation — Aeroplanes
- *Part III* — International Operations — Helicopters

Annex 8 — *Airworthiness of Aircraft*

Annex 11 — *Air Traffic Services*

Annex 15 — *Aeronautical Information Services*

Annex 19 — *Safety Management*

Procedures for Air Navigation Services — Air Traffic Management (PANS-ATM, Doc 4444)

Regional Supplementary Procedures (Regional SUPPs, Doc 7030)

Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services (Doc 8585)

Aircraft Type Designators (ICAO Doc 8643)

Manual on a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive (Doc 9574)

Performance-based Navigation Manual (PBN) (Doc 9613)

Manual on Airspace Planning Methodology for the Determination of Separation Minima (Doc 9689)

Safety Management Manual (SMM) (Doc 9859)

Performance-Based Communication and Surveillance Manual (Doc 9869)

Operating Procedures and Practices for Regional Monitoring Agencies in Relation to the Use of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive (Doc 9937)

Location Indicators (Doc 7910)

Designators for Aircraft Operating Agencies, Aeronautical Authorities, and Services (Doc 8585)

Aircraft Type Designators (Doc 8643)

IATA documents

Airline Coding Directory

4. Future developments

4.1 In order to keep this manual relevant and accurate, suggestions for improving it in terms of format, content or presentation are welcome. Any such recommendation or suggestion will be examined and, if found suitable, will be included in regular updates to the manual. Regular revision will ensure that the manual remains both pertinent and accurate. Comments on this manual should be addressed to:

The Secretary General

International Civil Aviation Organization
999 Boulevard Robert-Bourassa
Montreal, Quebec, Canada H3C 5H7

DRAFT

Chapter 1. Definitions

1.1 Terms and definitions

When the following terms are used in this document they have the following meanings.

Note.— Where the term has “(ICAO)” annotated, the term has already been defined as such in Annexes and Procedures for Air Navigation Services (PANS).

Term

ADS-C service. A term used to indicate an ATS service that uses ADS-C.

Note.— ICAO Doc 4444 does not include ADS-C in its definition for ATS surveillance system. Therefore, an ATS surveillance service does not consider those provided by means of the ADS-C application, unless it can be shown by comparative assessment to have a level of safety and performance equal to or better than monopulse SSR.

Aeronautical Information Publication (AIP). A publication issued by or with the authority of a State and containing aeronautical information of a lasting character essential to air navigation. (ICAO)

Air navigation services provider (ANSP). The organization(s) that operate(s) on behalf of a State to manage air traffic and airspace safely, economically and efficiently through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions.

Aircraft address. A unique combination of 24 bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance. (ICAO)

Aircraft identification. A group of letters, figures or a combination thereof which is either identical to, or the coded equivalent of, the aircraft call sign to be used in air-ground communications, and which is used to identify the aircraft in ground-ground air traffic services communications. (ICAO)

Note 1.— The aircraft identification does not exceed 7 characters and is either the aircraft registration or the ICAO designator for the aircraft operating agency followed by the flight identification.

Note 2.— ICAO designators for aircraft operating agencies are contained in ICAO Doc 8585.

Aircraft registration. A group of letters, figures or a combination thereof which is assigned by the State of Registry to identify the aircraft.

Note.— Also referred to as registration marking.

Appropriate authority.

- a) Regarding flight over the high seas: The relevant authority of the State of Registry.
- b) Regarding flight other than over the high seas: The relevant authority of the State having sovereignty over the territory being overflown. (ICAO)

Area navigation (RNAV) specification. See navigation specification. (ICAO)

Term

ATM operation. An individual operational component of air traffic services. Examples of ATM operations include the application of separation between aircraft, the re-routing of aircraft, and the provision of flight information.

ATS surveillance service. A term used to indicate a service provided directly by means of an ATS surveillance system. (ICAO)

ATS surveillance system. A generic term meaning variously, ADS-B, PSR, SSR or any comparable ground-based system that enables the identification of aircraft.

Note.— *A comparable ground-based system is one that has been demonstrated, by comparative assessment or other methodology, to have a level of safety and performance equal to or better than monopulse SSR.*

(ICAO)

Automatic dependent surveillance — broadcast (ADS-B). A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link. (ICAO)

Automatic dependent surveillance — contract (ADS-C). A means by which the terms of an ADS-C agreement will be exchanged between the ground system and the aircraft, via a data link, specifying under what conditions ADS-C reports would be initiated, and what data would be contained in the reports. (ICAO)

Note.— *The abbreviated term “ADS contract” is commonly used to refer to ADS event contract, ADS demand contract, ADS periodic contract or an emergency mode.*

Call sign. The designator used in air-ground communications to identify the aircraft and is equivalent to the encoded aircraft identification.

Collision risk. The expected number of midair collisions in a prescribed volume of airspace for a specific number of flight hours due to loss of planned separation. (Note: One collision is considered to produce two accidents)

Controller-pilot data link communications (CPDLC). A means of communication between controller and pilot, using data link for ATC communications. (ICAO)

Core lateral navigational performance. That portion of overall lateral navigational performance which accounts for the bulk of observed lateral errors and which can be characterized by a single statistical distribution, usually symmetric about the mean lateral error with the frequency of increasing-magnitude errors decreasing at least exponentially.

Current flight plan. (See flight plan).

Data link initiation capability (DLIC). A data link application that provides the ability to exchange addresses, names and version numbers necessary to initiate data link applications. (ICAO)

Term

Filed flight plan. (See flight plan).

Flight identification. A group of numbers, which is usually associated with an ICAO designator for an aircraft operating agency, to identify the aircraft in Item 7 of the flight plan.

Flight information region (FIR). An airspace of defined dimensions within which flight information service and alerting service are provided. (ICAO)

Flight plan. Specified information provided to air traffic services units, relative to an intended flight or portion of a flight of an aircraft. (ICAO)

A flight plan can take several forms, such as:

Current flight plan (CPL). The flight plan, including changes, if any, brought about by subsequent clearances. (ICAO)

Note 1.— When the word “message” is used as a suffix to this term, it denotes the content and format of the current flight plan data sent from one unit to another.

Filed flight plan (FPL). The flight plan as filed with an ATS unit by the pilot or a designated representative, without any subsequent changes. (ICAO)

Note 2.— When the word “message” is used as a suffix to this term, it denotes the content and format of the filed flight plan data as transmitted.

Aircraft active flight plan. The flight plan used by the flight crew. The sequence of legs and associated constraints that define the expected 3D or 4D trajectory of the aircraft from takeoff to landing. (RTCA/EUROCAE)

Horizontal separation. The spacing provided between aircraft in the horizontal (lateral or longitudinal) plane to avoid collision.

Large lateral deviation (LLD). Any lateral deviation from the current flight plan track that is greater than a regionally agreed value pertinent to the applied separation minimum.

Large longitudinal error (LLE). Any unexpected change in longitudinal separation between an aircraft pair, or for an individual aircraft the difference between an estimate for a given fix and the actual time of arrival over that fix, as applicable.

Note.— See [Appendix B](#), which provides a form for reporting LLEs, and [Appendix G](#) for an example of criteria used by the Asia/Pacific region.

Monitoring organization. A body that performs monitoring functions for the application of performance-based horizontal separation minima.

Term

Navigation specification. A set of aircraft and aircrew requirements needed to support Performance-based Navigation operations within a defined airspace. There are two kinds of navigation specification:

RNAV specification. A navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV (e.g. RNAV 5, RNAV 1).

RNP specification. A navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP (e.g. RNP 4, RNP APCH).

Note.— *Volume II of [Doc 9613] contains detailed guidance on navigation specifications.*

(Refer to PBN Manual Doc. 9613 4th Edition, Volume 1 - Concept and Implementation Guidance, Explanation of Terms, page 1-(xviii))

Occupancy. A parameter of the collision risk model which is twice the count of aircraft proximate pairs in a single dimension divided by the total number of aircraft flying the candidate paths in the same time interval.

Operational approval. An approval granted to the operator by a State authority after being satisfied that the operator meets specific aircraft and operational requirements.

Operational risk. The risk of collision due to operational errors and in-flight contingencies.

Overall risk. The risk of collision due to all causes, which includes the technical risk and the operational risk.

Passing frequency. The frequency of events in which the centers of mass of two aircraft are at least as close together as the metallic length of a typical aircraft when traveling in the same or opposite directions on adjacent routes separated by the lateral separation standard at the same flight level.

Performance-based communication (PBC). Communication based on performance specifications applied to the provision of air traffic services.

Note.— *An RCP specification includes communication performance requirements that are allocated to system components in terms of communication transaction time, continuity, availability, integrity, safety and functionality needed for the proposed operation in the context of a particular airspace concept.*

Performance-based navigation (PBN). Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.

Note.— *Performance requirements are expressed in navigation specifications (RNAV specification, RNP specification) in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept. (ICAO)*

Term

Performance-based surveillance (PBS). Surveillance based on performance applied to the provision of air traffic services.

Note.— *An RSP specification includes surveillance performance requirements that are allocated to system components in terms of surveillance data delivery time, continuity, availability, integrity, accuracy of the surveillance data, safety and functionality needed for the proposed operation in the context of a particular airspace concept.*

Procedural control. Term used to indicate that information derived from an ATS surveillance system is not required for the provision of air traffic control service. (ICAO)

Procedural separation. The separation used when providing procedural control. (ICAO)

Required communication monitored performance (RCMP). The maximum time against which ACP is assessed.

Required communication performance (RCP) specification. A set of requirements for air traffic service provision, aircraft capability, and operations needed to support performance-based communication.

Note.— *The term RCP, currently defined as “a statement of performance requirements for operational communication in support of specific ATM functions”, has been revised to align the concept of PBC with the concept of PBN. The term RCP is now used in the context of a specification that is applicable to the prescription of airspace requirements, qualification of ATS provision, aircraft capability, and operational use, including post-implementation monitoring (e.g. RCP 240 refers to the criteria for various components of the operational system to ensure an acceptable intervention capability for the controller is maintained).*

Required navigation performance (RNP) specification. See navigation specification. (ICAO)

Required surveillance monitored performance (RSMP). The maximum time against which ASP is assessed.

Required surveillance performance (RSP) specification. A set of requirements for air traffic service provision, aircraft capability, and operations needed to support performance-based surveillance.

Note.— *The term RSP is used in the context of a specification that is applicable to the prescription of airspace requirements, qualification of ATS provision, aircraft capability, and operational use, including post-implementation monitoring (e.g. RSP 180 refers to the criteria for various components of the operational system to ensure an acceptable surveillance capability for the controller is maintained).*

State of Design. The State having jurisdiction over the organization responsible for the type design. (ICAO)

State of Manufacture. The State having jurisdiction over the organization responsible for the final assembly of the aircraft. (ICAO)

Term

State of Registry. The State on whose register the aircraft is entered. (ICAO)

Note.— In the case of the registration of aircraft of an international operating agency on other than a national basis, the States constituting the agency are jointly and severally bound to assume the obligations which, under the Chicago Convention, attach to a State of Registry. See, in this regard, the Council Resolution of 14 December 1967 on Nationality and Registration of Aircraft Operated by International Operating Agencies which can be found in Policy and Guidance Material on the Economic Regulation of International Air Transport (Doc 9587).

State of the Operator. The State in which the operator's principal place of business is located or, if there is no such place of business, the operator's permanent residence. (ICAO)

Target level of safety (TLS). A generic term representing the level of risk which is considered acceptable in particular circumstances.

Technical risk. The risk of collision associated with aircraft navigational performance.

1.2 Acronyms

When the following acronyms are used in this document they have the following meanings. Where the term has “(ICAO)” annotated, the acronym has already been defined as such in Annexes and/or PANS.

Acronym	Description
ADS-B	Automatic dependent surveillance – broadcast
ADS-C	Automatic dependent surveillance – contract
ANSP	Air navigation service provider
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic services
CPDLC	Controller pilot data link communication
CRM	Collision risk model
EMA	En-route Monitoring Agency
FIR	Flight information region
ICAO	International civil aviation organization
LLD	Large lateral deviation
LLE	Large longitudinal error
MASPS	Minimum aviation system performance standard
NM	Nautical miles
PBC	Performance-based communication
PBCS	Performance-based communication and surveillance
PBN	Performance-based navigation
PBS	Performance-based surveillance
PIRG	Planning and Implementation Regional Group

Acronym	Description
RCP	Required communication performance
RNAV	Area navigation
RNP	Required navigation performance
RSP	Required surveillance performance
RVSM	Reduced vertical separation minimum
SASP	Separation and Airspace Safety Panel
SSR	Secondary surveillance radar
TLS	Target level of Safety
TSD	Traffic sample data

Chapter 2. DESCRIPTION OF THE FUNCTIONS NECESSARY TO MONITOR THE APPLICATION OF PERFORMANCE-BASED HORIZONTAL SEPARATION MINIMA

2.1 Description

2.1.1 Groups of States or Regions establish a monitoring programme to support the safe use of performance based horizontal separation minima. Effective provision of this programme relies heavily on safety data provided by States. Such data is contingent on a State having a safety management system mature enough to enable a robust safety reporting culture, providing data such as traffic samples, and importantly a means to investigate and develop controls and mitigations for risks identified through this process. Guidance on safety management principles is provided in the Safety Management Manual (SMM) Doc 9859.

2.1.2 The functions defined in this chapter of the document directly support a Region or State implementation of safety management principles through the pre-implementation assessment and ongoing performance monitoring of an airspace system. The airspace safety assessment and monitoring functionality enables a measurement of any practical drift from the system safety baseline following operational deployment. These functions should be undertaken using a combination of data collected through predictive, proactive and reactive means.

2.1.3 This document assumes that groups of States or ICAO Regions establish a safety oversight group that is responsible for:

- a) monitoring the safety of performance-based horizontal separation minima deployed in the region; and
- b) taking action when the operational performance of the airspace, where such minima are deployed, has deviated significantly from the system design baseline.

2.1.4 The safety oversight group would, in turn, report periodically the status of separation-related safety to the region's planning and implementation regional group (PIRG) or regional airspace safety group (RASG).

2.1.5 The safety oversight group would establish a programme for carrying out specific functions and duties to provide these monitoring services. The safety oversight group may establish a separate organization to provide these functions, or allocate these duties and responsibilities to existing groups within the existing PIRG sub-groups. These functions, duties and responsibilities are summarized in this chapter.

2.1.6 Within a region, these functions could be combined with the functions of the Regional Monitoring Agency (RMA), established to provide airspace safety assessment and monitoring services to support the continued safe use of the reduced vertical separation minimum (RVSM), and supported by other monitoring programmes, such as the performance-based communication and surveillance (PBCS) monitoring programme established by air navigation service providers (Doc 9869).

2.2 Duties and Responsibilities for Monitoring the Application of Performance-based Horizontal Separation Minima

2.2.1 The associated duties and responsibilities are:

- a) to establish and maintain a database of operational approvals specific to the horizontal separation minima being applied in the airspace;

- b) to receive reports of large horizontal deviations identified during monitoring; to take the necessary action with the relevant State authority and operator to determine the likely cause of the lateral deviation and/or longitudinal error, and to verify the approval status of the relevant operator;
- c) to proactively undertake data collections as required by the regional oversight group which oversees the safety of regional airspace to:
 - 1) analyze data collected on a predictive and proactive basis to detect lateral and longitudinal deviation trends and, hence, to take action as specified in 1.2.1 b);
 - 2) investigate the navigational performance of the aircraft in the core of the distribution of lateral deviations;
 - 3) establish or add to databases of operational performance, including lateral navigation and/or communication and/or surveillance performance for:
 - i) the aircraft population;
 - ii) aircraft types or categories;
 - iii) individual airframes;
 - 4) determine the appropriate method to monitor longitudinal errors;
- d) to archive results of performance monitoring and to conduct periodic risk assessments that proactively identify aberrant changes in operational performance from agreed regional safety goals;
- e) to initiate necessary remedial actions and coordinate with oversight groups as necessary in the light of monitoring results;
- f) to monitor the level of risk as a consequence of operational errors and inflight contingencies identified from a range of available safety data as follows:
 - 1) determine, wherever possible, the root cause of each lateral deviation or longitudinal error together with its size and duration;
 - 2) calculate the frequency of occurrence;
 - 3) assess the overall risk in the system against the overall safety objectives; and
 - 4) initiate remedial action as required;
- g) to initiate checks of the approval status of aircraft operating in the relevant airspace, identify non-approved operators and aircraft using the airspace and notify the appropriate State of Registry/State of the Operator accordingly; and
- h) to submit reports as required to the PIRG/RASG through the region's safety oversight group.

2.3 Process for establishing the functions necessary to monitor the application of performance-based horizontal separation minima

2.3.1 An organization should perform these functions either locally or on the basis of a bilateral, multilateral or regional air navigation agreement, as applicable, depending on the area of operations.

2.3.2 In order to effectively carry out the necessary duties and responsibilities, an acceptable level of competence must be demonstrated. Competence may be demonstrated by:

- a) previous airspace safety performance monitoring experience; or
- b) participation in ICAO technical panels or other bodies which develop horizontal separation requirements or criteria for establishing separation minima based on performance based operations; or
- c) establishment of a formal relationship with an organization qualified under (a) or (b), resulting in the latter organization being confident to provide an endorsement of the new organization as capable of carrying out the duties and responsibilities detailed in 1.2.1

2.3.3 Once competence has been demonstrated, including presentation of sufficient material to the regional oversight group on which to make a reasoned assessment, the safety oversight group and the PIRG should provide a formal approval.

2.3.4 Monitoring organizations should publish a list of flight information regions (FIRs) and/or ICAO contracting States for which they provide monitoring services for application of performance-based horizontal separation minima.

Chapter 3. RESPONSIBILITIES AND STANDARDIZED PRACTICES

3.1 Purpose of this chapter

3.1.1 The purpose of this chapter is to document experience gained by organizations assisting the introduction of and supporting the continued safe-use of horizontal separation minima in order to describe the specific functions necessary to support the implementation and monitor the continued safe-use of the separation minima. Where necessary to ensure standardized practices, detailed guidance is elaborated further in appendices.

3.1.2 This chapter describes activities an organization may use to fulfill either pre- or post-implementation responsibilities. The main difference between the pre- and post- implementations for the organization is the frequency of the analyses. Throughout the pre-implementation phase, the organization should expect to perform frequent analyses in support of the introduction of the reduced horizontal separation minima. The monitoring organization should expect to perform the described activities on a periodic basis (e.g. annual) during the post-implementation phase.

3.1.3 **Figure 3-1** provides a flow chart of the implementation process and the post-implementation monitoring process for horizontal separation minima. The flow chart draws attention to the interrelationships between the implementation activities of the ANSP and the safety assessment and monitoring responsibilities. The oversight body should be informed of any aspects of the operational concept which it considers important in this respect.

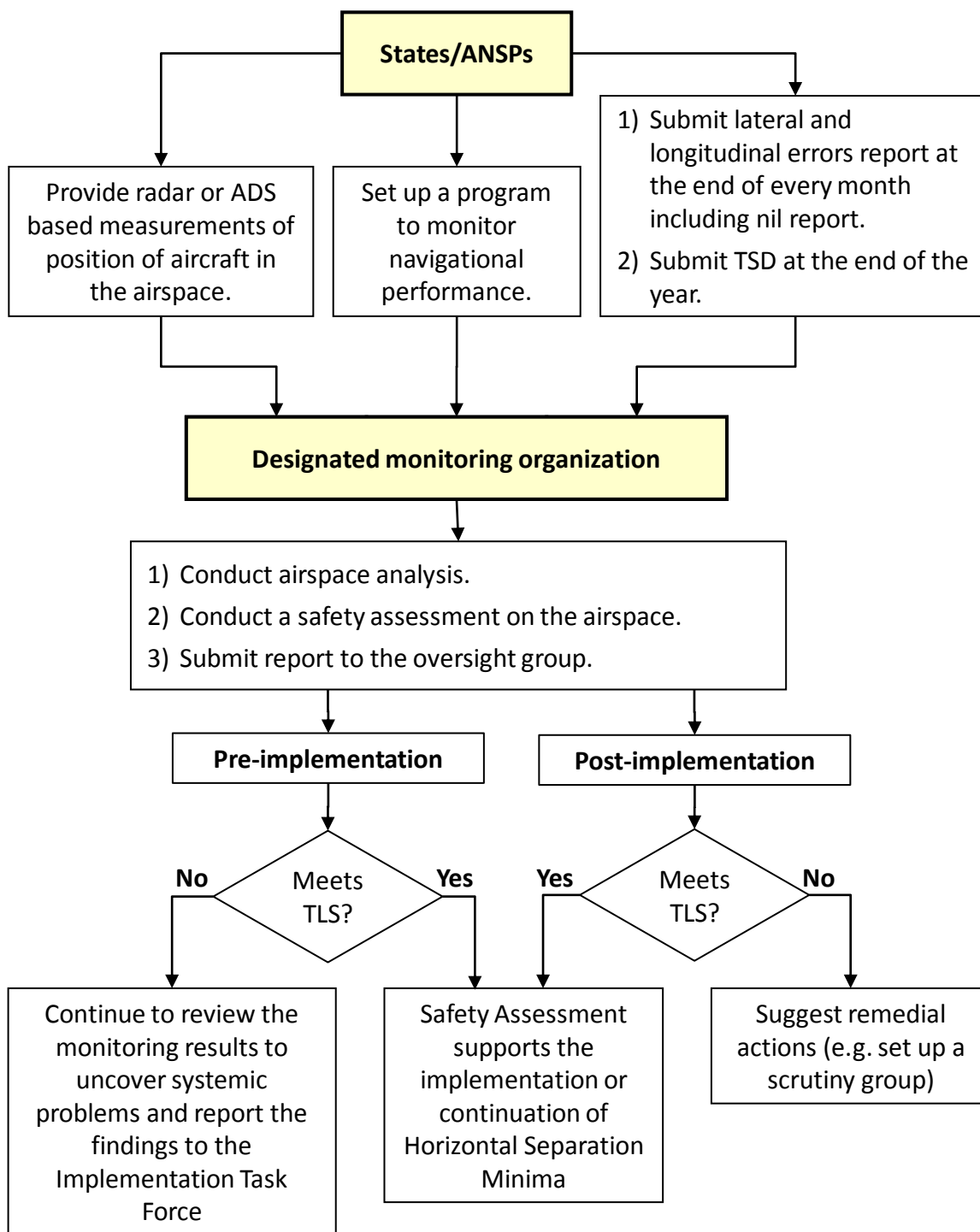


Figure 3-1. Pre/post-implementation horizontal separation minima flow chart

3.2 Establishing the Competence Necessary to Conduct a Safety Assessment in a Region

3.2.1 Conducting a safety assessment is a complex task requiring specialized skills which are not practiced widely. As a result, prior to receiving approval from the regional safety oversight group to perform the functions described in this document, the organization will need to demonstrate to that group the necessary competence to complete the required tasks.

3.2.2 Ideally, a monitoring organization will have the internal competence to conduct a safety assessment. However, recognizing that personnel with the required skills may not be available internally, a monitoring organization may find it necessary to augment its staff, through the use of personnel assigned by States to the regions planning and implementation groups, through arrangements with another established organization possessing the necessary competence.

3.2.3 If it is necessary to use another established organization to conduct a safety assessment, that organization must have the competence to judge that such an assessment is valid. This competence could be acquired through an arrangement with an organization with experience in conducting safety assessments.

3.2.4 The safety assessment must reflect the factors that influence collision risk within the airspace where the horizontal separation will be applied. Thus, a method to collect and organize pertinent data and other information descriptive of these airspace factors needs to be established. Data sources from other airspace where horizontal separation has been implemented may assist in conducting a safety assessment. However, these data may not be used as the sole justification for concluding that the TLS will be met in another airspace unless it is determined that the assumptions made in the safety assessment for the other airspace are applicable and valid for the relevant airspace.

3.2.5 When data from other airspace is used, a comparative safety assessment should be conducted to demonstrate that the assumptions made for the other airspace are valid for the relevant airspace. Basic airspace characteristics should be included in the comparative study, these include estimates of annual flying hours, number of flight operations, and traffic densities. The key assumptions to evaluate depend on capabilities, such as RCP, RSP and RNP/RNAV, and the specific reduced separation. For the relevant airspace, the comparative study should examine the observed system behavior, such as the CPDLC transaction times, data link outages and durations, and occurrences of navigational errors.

3.3 Responsibilities and Standardized Practices for the Pre-Implementation Phase

3.3.1 Review of Operational Concept

3.3.1.1 Experience has shown that the operational concept for the application of horizontal separation minima adopted by bodies overseeing these applications can substantially affect the collision risk in airspace.

3.3.1.2 The operational concept agreed by the body overseeing horizontal separation implementation, generally the ANSP, should be reviewed carefully with a view to identify any features of airspace use which may influence risk.

3.3.2 Steps for Conducting a Pre-Implementation Safety Assessment

3.3.2.1 When implementing a performance-based horizontal separation minima, it is recommended to conduct a safety assessment in accordance with the requirements detailed in ICAO

Annex 11 – Air Traffic Services (Chapter 2, section 2.27.5), ICAO Doc 4444, ATM/501 – Procedures for Air Navigation Services, Air Traffic Management (Chapter 2, Section 2.6), ICAO Annex 19 – Safety Management, and the supporting guidance material contained in the Safety Management Manual (ICAO Doc 9859), including the development of hazard identification, risk management and mitigation procedures tables.

3.3.2.2 **Table 3-1** provides an overview of the minimum steps considered necessary for a Region to undertake a safety assessment. These Steps are provided to describe the entire safety assessment process for the Region. The monitoring organization should expect to participate in the process beginning with Steps 3 and 4.

Table 3-1. Steps for conducting a safety assessment

Ref	Description
Step 1	Undertake widespread regional consultation with all possible stakeholders and other interested parties.
Step 2	Develop an airspace design concept or ensure that the proposed separation minima will fit the current airspace system and regional or State airspace planning strategy.
Step 3	Review related material for performance based horizontal separation minima. These documents include ICAO Annex 11 – Air Traffic Services, ICAO Doc 4444, ICAO Doc 9869 –Performance-Based Communication and Surveillance (PBCS) Manual, ICAO Doc 9613 – Performance-based Navigation (PBN) Manual, and ICAO Circulars that provide guidance on the implementation of certain separation minima. Note the specific assumptions, constraints, enablers and system performance requirements in the reference documents.
Step 4:	Compare assumptions, enablers, and system performance requirements in the documents cited in Step 3 with the regional operational environment, infrastructure and capability.

Ref	Description
Step 5	<p>If a region has determined that the change proposal for that region is equal to or better than the requirements and system performance in the documents cited in Step 3, then the region must undertake safety management activities including:</p> <ul style="list-style-type: none"> a) formal hazard and consequence(s) identification, and safety risk analysis activities including identification of controls and mitigators; b) implementation plan; c) techniques for hazard identification/safety risk assessment which may include: <ul style="list-style-type: none"> 1) the use of data or experience with similar services/changes; 2) quantitative modeling based on sufficient data, a validated model of the change, and analyzed assumptions; 3) the application and documentation of expert knowledge, experience and objective judgment by specialist staff; and 4) a formal analysis in accordance with appropriate safety risk management techniques as set out in ICAO Doc 9859; d) identification and analysis of human factors issues identified with the implementation including those associated with Human Machine Interface matters; e) simulation where appropriate; f) operational training; and g) regulatory approvals
Step 6	<p>If a region has determined that the change proposal for that region is not equal to the requirements and system performance in the documents cited in Step 3, then the region must:</p> <ul style="list-style-type: none"> a) consider alternative safety risk controls to achieve the technical and safety performance that matches the documents cited in Step 3; or, b) conduct appropriate quantitative risk analysis for the development of a local standard in accordance with Doc 9689.
Step 7	<p>Develop suitable safety assessment documentation including a safety plan and associated safety cases.</p>
Step 8	<p>Implementation activities should include:</p> <ul style="list-style-type: none"> a) trial under appropriate conditions; b) expert panel to undertake scrutiny of proposals and development of identified improvements to the implementation plan; c) develop an appropriate backup plan to enable reversion if necessary; and d) continuous reporting and monitoring results of incidents, events, observations.
Step 9	<p>Develop suitable post-implementation monitoring and review processes.</p>

3.4 Responsibilities and Standardized Practices for Both Pre-Implementation and Post-Implementation Phases

3.4.1 Establishment and Maintenance of Database of Performance Based Operation Approvals

3.4.1.1 The experience gained through the introduction of the RVSM has shown that the concept of utilizing monitoring organizations is effective in ensuring safety in a region. Monitoring organizations have a significant role to play in all aspects of the safety monitoring process. One of the functions for monitoring the application of performance-based horizontal separation minima is to establish a database of operators and aircraft types/systems approved for performance-based communications (PBC), performance-based navigation (PBN) and performance-based surveillance (PBS) operations by the appropriate authority. Guidance on these approvals is contained in Doc 9613 and Doc 9869.

3.4.1.2 Aviation is a global industry; many operators may be approved for performance based operations and their approvals registered with an organization performing regional monitoring functions to support the application of horizontal separation minima that rely on performance-based operations. Thus, there is considerable opportunity for sharing the information from monitoring functions among the regions. A region or sub-region introducing horizontal separation predicated on performance-based specifications may need its own designated monitoring organization to act as a focal point for the collection and collation of approvals for aircraft operators operating solely in that region. However, because some aircraft operators may have approvals from States outside the Region, the organization will need to coordinate with other regional monitoring organizations to determine the aircraft operator approval status.

3.4.1.3 To avoid duplication by States in registering approvals with any specific regional monitoring organization, the concept of a designated monitoring organization for processing approval data has been established. Under this concept, all States are associated with a specified designated monitoring organization for reporting performance based operation approvals. A listing of States and the respective designated monitoring organization for performance based operation approvals should be maintained on ICAO Regional websites. Designated monitoring organizations should contact the appropriate monitoring organization for a State, to address safety matters for operators registered with that State.

3.4.1.4 In airspace where implementation of performance-based separation is planned, not all aircraft may have the required approvals. Therefore, a State's designated monitoring organization is required to establish a means to coordinate with the State authority to maintain a precise description of the approval information required. [Appendix A, section A.1](#) provides typical forms, with a brief description of their use, that can be transmitted to a State authority to obtain information on aircraft performance based operation approval status.

3.4.1.5 To avoid duplication of work effort, wherever possible, any regional monitoring organization should collect State approval information from the regional monitoring organization associated with the State of the Operator. This collection will be facilitated if the regional monitoring organization maintains a database of these State approvals in a similar electronic form.

3.4.1.6 [Appendix A, section A.2](#) describes the minimum database content required, the format in which it should be maintained, a description of the data to be shared and procedures for data sharing.

3.4.2 Monitoring of Operator Compliance with State Approval Requirements

3.4.2.1 After the database described in [section 3.4.1](#) has been established, monitoring of operator compliance with State approval requirements should begin and be maintained while performance-based horizontal separation minima is being applied in the airspace. The aircraft approval status as listed in the data base is compared with the aircraft equipment and capability filed in the flight plan. This is required if State approval for performance based operations is a prerequisite for applying the horizontal separation in such airspace.

3.4.2.2 Two sources of information are needed to perform this monitoring:

- a) Aircraft identification (Item 7), aircraft type (Item 9), aircraft registration and PBC, PBN, and/or PBS capability indicated in items 10 and 18 of the flight plan; and
- b) the database of State PBC, PBN, or PBS approval status, which is obtained from the State of the Operator or State of Registry.

3.4.2.3 As a minimum, compliance monitoring of the complete airspace for at least a 30-day period annually should be conducted. More frequent monitoring of operator approvals enables non-compliant operators to be efficiently identified and any risk associated with their operation in the airspace mitigated. **Error! Reference source not found.** provides a flow chart depicting the process required for monitoring of operator compliance with State approvals.

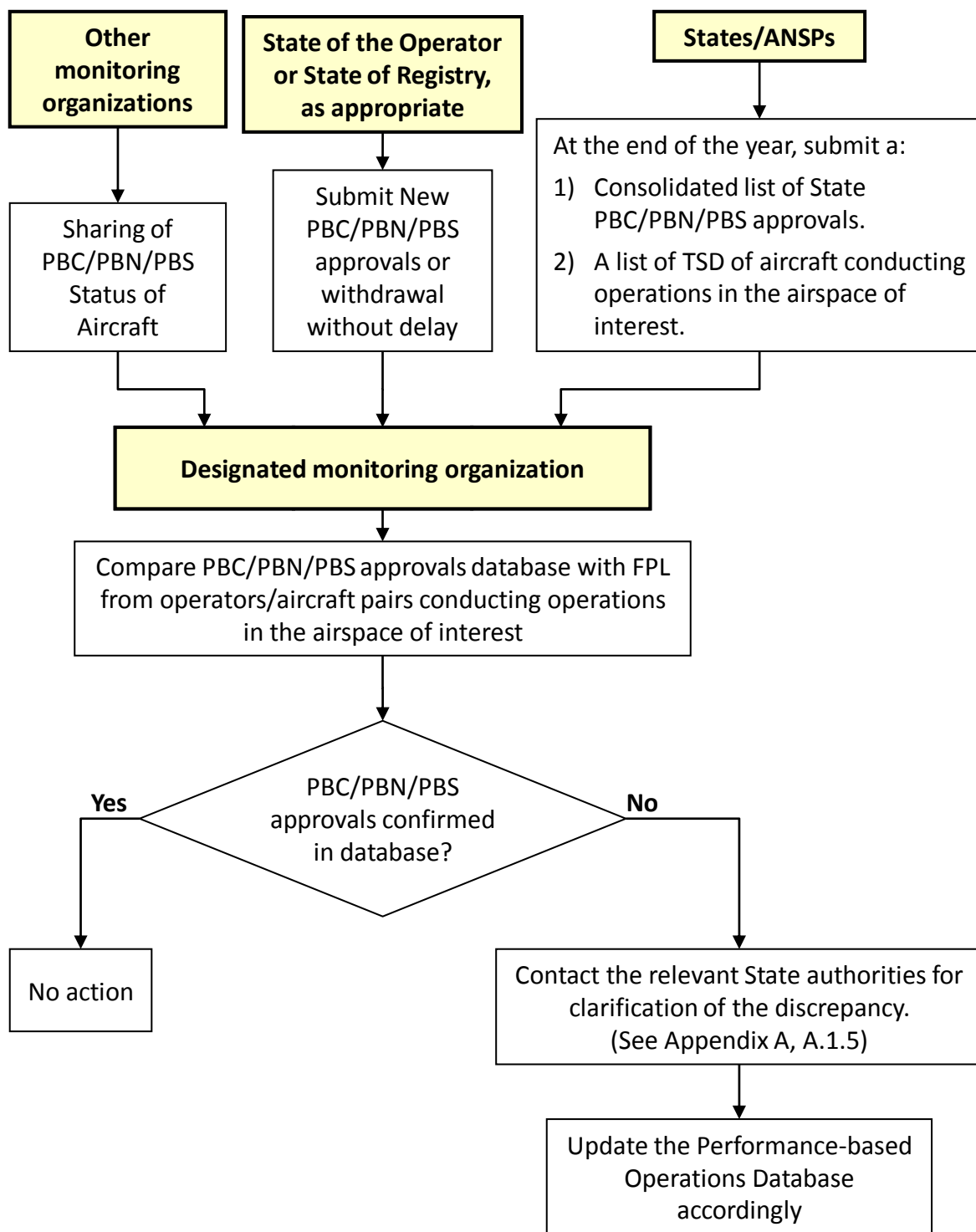


Figure 3-2. Monitoring of operator compliance with State approval requirements flow chart

3.4.2.4 When conducting compliance monitoring, the filed equipment and capability indicated in the flight plan for each aircraft movement should be compared to the database of State approval status for

the operator and the particular aircraft type/system within the operator's fleet. When a flight plan shows a performance based operational approval not confirmed in the database, the monitoring organization should officially notify the appropriate organization using a letter similar in form to that shown in [Appendix A, section A.1.5](#) to resolve the discrepancy. The appropriate organization is as follows:

- a) State of the Operator or State of Registry, as appropriate, if the State is assigned to the designated monitoring organization; or
- b) The designated monitoring organization to which the State of the Operator or State of Registry is assigned.

3.4.2.5 The responsibility to take any action should an operator be found to have filed an incorrect declaration of State approval for performance-based operations lies clearly with the State authority, not the designated monitoring organization. The responsibility of the monitoring organization is only to officially notify the appropriate State authority of the discrepancy, and provide advice or information as requested by the State authority.

3.4.3 Monitoring of Communication, Navigation, and Surveillance Performance

3.4.3.1 General

3.4.3.1.1 The monitoring functions include the collection of information necessary to monitor communication, navigational and surveillance performance as part of the risk assessment. Procedures must be instituted to monitor core navigational performance, speed variations, related communication and surveillance performance, and to collect information descriptive of large lateral deviations (LLDs) and large longitudinal errors (LLEs).

3.4.3.2 Monitoring Core Navigational Performance

3.4.3.2.1 As required by the regional oversight group, the navigational performance of the aircraft in the core of the distribution of lateral navigational accuracy by comparing aircraft reported position information with non-aircraft-generated position information such as radar data will be investigated. The analysis of core navigation performance contributes to the determination of lateral overlap probability used in conducting a safety assessment. Cooperation of States and ANSPs in monitoring horizontal core navigational performance through the use of appropriate ATS surveillance systems (e.g. secondary surveillance radar) must be enlisted. States and ANSPs have the responsibility to supply any requested data that will contribute to the evaluation of core navigational performance.

3.4.3.3 Monitoring Longitudinal Performance – Speed Variation

3.4.3.3.1 The safety assessment process will require evaluation of aircraft speed variation in the airspace. The analysis of aircraft speed variation contributes to the determination of horizontal overlap probability used in conducting a safety assessment. To accomplish this task, the cooperation of ANSPs must be enlisted in monitoring aircraft speed variation performance through the position reports and flight plan data, where appropriate. States and ANSPs have the responsibility to contribute to the analyses and supply any requested data that will contribute to the evaluation of longitudinal performance.

3.4.3.3.2 Aircraft speed variation can be monitored using aircraft position reports that contain estimates of next position. It may be necessary to utilize the instantaneous Mach speed information found

in automatic dependent surveillance – contract (ADS-C) reports, and when appropriate the cleared Mach speed, to evaluate adherence to assigned Mach speed. The regional monitoring organization must institute procedures to monitor speed variations, related communication and surveillance performance, and to collect information descriptive of large longitudinal errors (LLEs). [Appendix F](#) contains a description of the assumed speed variation distribution and other parameter used in the collision risk modeling.

3.4.3.4 Monitoring of Large Lateral Deviations (LLDs) and Large Longitudinal Errors (LLEs)

3.4.3.4.1 Experience has shown that LLDs and LLEs have had significant influence on the outcome of safety assessments before implementation of performance-based separation minimum. Accordingly, a principal monitoring function is to ensure the existence of a program to collect this information, assess the occurrences and initiate remedial action to correct systemic problems. [Section 3.4.4.4](#) provides guidance for initiating such remedial actions as may be necessary to resolve systemic problems uncovered by this program. One way to ensure the existence of such a program is to develop letters of agreement between States.

3.4.3.4.2 Within the airspace for which it is responsible, each ANSP will need to establish the means to detect and report the occurrence of LLDs and LLEs. Experience has shown that the primary sources for reports of LLDs and LLEs are the ATS units providing air traffic control services in the airspace where the performance-based separation will be applied. The surveillance information available to these units – in the form of voice reports or ADS-C reports and, where available, surveillance radar data or automatic dependent surveillance – broadcast (ADS-B) data – provide the basis for identifying LLDs and LLEs.

3.4.3.4.3 A program to assess the occurrence of LLDs and LLEs may include a regional Scrutiny Group to support the monitoring functions. A Scrutiny Group is comprised of operational and technical subject matter experts that support the evaluation and classification of LLDs and LLEs to determine their applicability to the collision risk estimate and for other purposes. Guidance on the functions of a Scrutiny Group is contained in [Appendix C](#).

3.4.3.4.4 The ANSP should provide reports of the occurrence of LLDs and LLEs where the magnitude of the deviation or error meets or exceeds the regionally agreed value. It is noted that several horizontal separation minima are available for application in oceanic and procedural airspace depending on the eligibility of the aircraft operator and the capability of the ATC support systems. The regionally agreed value for reporting LLDs and LLEs should be based on the smallest separation minima possible to relieve ATC from the responsibility of deciding whether a deviation or error occurred based on the RNP specification and the separation minima applied.

3.4.3.4.5 The ANSP should establish a program for ATS units to provide monthly reports of LLDs and LLEs. An example format for these reports is shown in [Appendix B](#). These reports should contain, as a minimum, the following information:

- a) Reporting unit;
- b) Location of deviation, either as latitude/longitude, ATS route waypoint or other ATC fix;
- c) Date and time of LLDs and LLEs;
- d) Sub-portion of airspace, such as established route system, if applicable;

- e) Flight identification and aircraft type;
- f) Actual flight level or altitude;
- g) Horizontal separation being applied;
- h) Size of deviation;
- i) Duration of large deviation;
- j) Cause of deviation;
- k) Any other traffic in potential conflict during deviation;
- l) Crew comments when notified of deviation;
- m) Fields 10 and 18 from the ICAO filed flight plan; and
- n) Remarks from ATS unit making report

3.4.3.4.6 Other sources for reports of LLDs and LLEs should also be explored. A monitoring organization is encouraged to determine if operators within the airspace for which it is responsible are willing to share pertinent summary information from internal safety oversight databases. In addition, a monitoring organization should inquire about access to State databases of safety incident reports which may be pertinent to the airspace. Voluntary reporting safety databases should also be examined, where these are available, as possible sources of LLDs and LLEs incidents in the airspace for which it is responsible.

3.4.3.4.7 While a monitoring organization will be the recipient and archivist for reports of LLDs and LLEs, it is important to note that it alone cannot be expected to conduct all activities associated with a comprehensive program to detect and report large horizontal deviations. Rather, the support of the regional oversight group overseeing the safety of separation minima, the ICAO Regional Office, appropriate implementation task forces, scrutiny groups or any other organization that can assist in the establishment of such a program should be enlisted.

3.4.3.5 Communication and Surveillance Performance Monitoring

3.4.3.5.1 Performance-based operations that are predicated on the performance of communication and surveillance systems, such as those used for controller-pilot data link communications (CPDLC), ADS-C and/or satellite voice (SATVOICE), require approvals to show initial compliance with performance specifications and post-implementation monitoring to show continued compliance. Means for obtaining initial approval and continued monitoring should be established prior to the introduction of reduced separation minimum. Guidance material for these initial approvals and establishing PBCS monitoring programmes is provided in ICAO Doc 9869. In the assessment of risk levels, it may be necessary to use data from PBCS monitoring programmes.

3.4.3.5.2 The safety assessment process will require evaluation of observed communication and surveillance system behavior, such as the following:

- a) CPDLC uplink transit times;
- b) Overdue ADS-C reports;
- c) Uplink messages with no response or an UNABLE response; and
- d) Communication service provider outages and the effect on operations in the airspace.

3.4.4 Conducting Safety Assessments and Reporting Results

3.4.4.1 Assembling a Sample of Traffic Movements from the Airspace

3.4.4.1.1 Samples of traffic movement data should be collected for the entire airspace where the horizontal separation will be implemented. As a result, ANSPs providing services within the airspace are required to cooperate in providing this data.

3.4.4.1.2 In planning the timing and duration of a traffic movement data sample, the importance of capturing any periods of heavy traffic flow which might result from seasonal or other factors should be taken into account. The duration of any traffic sample should be at least 30 days, with a longer sample period left to the judgment of the experts. As an example, by regional agreement, traffic sample data within the Asia/Pacific Region is collected by all States for the month of December each year for purposes of RVSM monitoring. During 2009, the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG) expanded the usage of this data under certain conditions to support regional implementations, including the horizontal separation minima.

3.4.4.1.3 The following information should be collected for each flight in the sample:

- a) date of flight;
- b) flight identification or aircraft call sign, in standard ICAO format;
- c) aircraft registration mark, if available;
- d) PBC approval type;
- e) PBN approval type;
- f) PBS approval type;
- g) aircraft type conducting the flight, as listed in the applicable edition of ICAO Doc 8643, Aircraft Type Designators;
- h) origin aerodrome, as listed in the applicable edition of ICAO Doc 7910, Location Indicators;
- i) destination aerodrome, as listed in the applicable edition of ICAO Doc 7910, Location Indicators;
- j) entry point (fix or latitude/longitude) into the airspace;
- k) time (UTC) at entry point;
- l) flight level (and assigned Mach number if available) at entry point;
- m) route after entry point;
- n) exit point from the airspace;
- o) time (UTC) at exit point;
- p) flight level (and assigned Mach number if available) at exit point;
- q) route before exit fix; and
- r) additional fix/time/flight-level/route combinations that the monitoring organization judges are necessary to capture the traffic movement characteristics of the airspace.

3.4.4.1.4 Where possible, in coordinating collection of the sample, it should be specified that information be provided in electronic form (for example, in a spreadsheet). [Appendix D](#) contains a sample specification for collection of traffic movement data in electronic form, where the entries in the first column may be used as column headings on a spreadsheet template.

3.4.4.1.5 Acceptable sources for the information required in a traffic movement sample could include one or more of the following: ATC observations, ATC automation system data, automated air traffic management system data and surveillance data such as SSR or ADS-B reports.

3.4.4.2 Safety Assessment

3.4.4.2.1 A State, or a group of States within a region, may call on the expertise developed for monitoring the application of performance-based horizontal separation minima to assist in the implementation of new separation minima. In order to conduct an implementation safety assessment, an in-depth knowledge of the use of the airspace is needed. For example, knowledge of expected operators and aircraft types, traffic flows, typical meteorological effects (such as equatorial meteorological effects, location of jet stream, etc), within the airspace which the horizontal separation will be implemented will inform the safety assessment process. Experience has shown that such knowledge can be gained through acquisition of charts and other material describing the airspace, and through periodic collection and analysis of samples of traffic movements within the airspace. The collation and consideration of this information results in a Know Your Airspace (KYA) analysis that documents matters of relevance to the horizontal separation implementation being proposed. An example of a typical KYA analysis is included as [Appendix E](#).

3.4.4.2.2 For some implementations of separation minima specified in the Doc 4444, collision risk modeling is required when it is determined that the assumptions made when developing the separation standards are not representative for the area where the standards are being implemented. A safety assessment should include an estimate of the risk of collision associated with the horizontal separation standard and a comparison of this risk to the established regional TLS or other associated safety metrics. The safety assessment will utilize collision risk methodologies that complement the safety management system (SMS) processes that are in place within the region. [Appendix F](#) of this document contains a summary of the parameters used in the performance based collision risk models for horizontal separation minima. Examples of internationally recognized Collision Risk Models (CRMs) used to support the development, implementation, and continued safe-use of horizontal separation minima are included in [Appendix G](#) and [Appendix H](#) of this document, and in Doc 9689. [Appendix G](#) and [Appendix H](#) contain example safety assessments for the South China Sea and New York oceanic airspace, respectively.

3.4.4.2.3 The regional safety oversight group will determine the safety reporting requirements (e.g. format and periodicity).

3.4.4.3 Determining Whether the Safety Assessment Satisfies the TLS

3.4.4.3.1 “Technical risk” is the term used to describe the risk of collision associated with aircraft performance. Some of the factors which contribute to technical risk are:

- a) errors in aircraft communication, navigation and surveillance systems; and
- b) aircraft equipment failures resulting in unmitigated deviation from the cleared flight path, including those where not following the required procedures further increases the risk.

3.4.4.3.2 “Operational risk” is the term used to describe the risk of collision due to operational errors and in-flight contingencies. The term “operational error” is used to describe any horizontal deviation of an aircraft from the correct flight path as a result of incorrect action by ATC or the flight crew. Examples of such actions include:

- a) a flight crew misunderstanding an ATC clearance, resulting in the aircraft operating on a flight path other than that issued in the clearance;
- b) ATC issuing a clearance which places an aircraft on a flight path where the separation minimum with other aircraft cannot be maintained;
- c) a coordination failure between ATS units in the transfer of control responsibility for an aircraft, resulting in either no notification of the transfer or in transfer at an unexpected transfer point;
- d) weather deviation (Note: these deviations may be instances where the aircraft captain initiates the maneuver using operational authority but without advising ATC, and are not necessarily deemed as being incorrect action. However, they still contribute to operational risk and should be reported).

3.4.4.3.3 The TLS which must be satisfied is established by regional agreement and documented in the Regional Supplementary Procedures (Doc 7030). For example, the generic Asia/Pacific TLS is presently established, for each dimension (lateral, longitudinal and vertical), as 5×10^{-9} fatal accidents per flight hour due to loss of planned separation; however, specific TLS values may be determined by ICAO for application of a particular separation minimum.

3.4.4.4 Remedial Actions

3.4.4.4.1 Remedial actions are those measures taken to remove causes of systemic problems associated with factors affecting the implementation of the performance-based horizontal separation minima. Remedial actions may be necessary to control or mitigate the causes of problems such as the following:

- a) failure of an aircraft to comply with performance based operation requirements;
- b) aircraft operating practices resulting in LLDs and LLEs; and
- c) operational errors.

3.4.4.4.2 Monitoring results should be periodically reviewed by the designated monitoring organization and the associated regional Scrutiny Group in order to determine if there is evidence of any recurring problems or adverse trends. Guidance on the functions of a Scrutiny Group is contained in Appendix C.

3.4.4.4.3 As a minimum, an annual review of reports of LLDs and LLEs should be conducted with a view toward uncovering systemic problems and initiating remedial action. Should such problems be identified, the findings should be reported to the body overseeing horizontal separation implementation, or to the regional oversight group charged with monitoring the safety of separation minima. Included in the report should be the details of LLDs and LLEs suggesting the root cause of the problem.

Appendix A MANAGING PERFORMANCE-BASED OPERATIONAL APPROVALS

This appendix provides:

- a) Forms for use in obtaining records of performance-based operational approvals from a State authority ([Section A.1](#)); and
- b) Minimal informational content for each state performance-based operation approval to be maintained in electronic form ([Section A.2](#)).

A.1 Forms for use in obtaining records of performance-based operational approvals from a State authority

A.1.1 General - forms

A.1.1.1 The following forms are provided for the collection of essential information relating to State performance-based operational approvals:

- a) Point of Contact Details for Matters Relating to performance-based operational approvals ([Section A.1.2](#));
- b) Record of State performance-based operational approval ([Section A.1.3](#));
- c) Withdrawal of State performance-based operational approval ([Section A.1.4](#)); and
- d) Letter to State authority requesting clarification of the state performance based operation approval status of an operator ([Section A.1.5](#)).

A.1.1.2 The following provides guidance to complete the forms provided in this appendix:

- a) It is important to have an accurate record of a point of contact for any queries that might arise from the monitoring of horizontal separation. Recipients are therefore requested to include a completed form provided in [section A.1.2](#) with their first reply to the designated monitoring organization. Thereafter, there is no further requirement unless there has been a change to the information requested on the form.
- b) The form provided in [section A.1.3](#) must be completed for each operator/aircraft granted a performance based operational approval.
- c) The form provided in [section A.1.4](#) must be completed and submitted immediately whenever a State of the Operator or State of Registry has cause to withdraw its performance-based operational approval for a specific aircraft type/system within a specific operator's fleet.
- d) Note: the fields in the forms provided in [section A.1.3](#) and [section A.1.4](#) should be completed as indicated [Table A- 1](#).
- e) The form provided in [section A.1.5](#) should be used to confirm the performance based operation approval status that may be shown in filed flight plan but not in the database of State approvals.

Table A- 1. Instructions for completing fields in Forms A2 and A3

Fields	Instruction
State of Registry State of Operator State of Performance Based Operational Approval	Enter the 2-letter ICAO identifier as contained in ICAO Doc 7910. In the case of there being more than one identifier designated for the State, use the letter identifier that appears first.
Operator Identifier	Enter the operator's 3 letter ICAO identifier as contained in ICAO Doc 8585. For International General Aviation, enter "IGA". If none, place an X in this field and enter the name of the operator/owner in the Remarks row.
Operator Type	Enter or Select Operator Type. E.g. Civil or Military
Registration Date Date of Approval Date of Expiry	Enter date in dd/mm/yyyy format, e.g. for 26 October 2013 enter 26/10/2013.
Aircraft Type	Enter the ICAO designator as contained in ICAO Doc 8643, e.g., for Airbus A320-211, enter A320; for Boeing B747-438 enter B744.
Aircraft Series	Enter series of aircraft type or manufacturer's customer designation, e.g., for Airbus A320-211, enter 211; for Boeing B747-438, enter 400 or 438.
Mode S Address Code (Hex)	Enter ICAO allocated Aircraft Mode S address code in hexadecimal format.
PBC Approval Type	Enter or select the type of PBC Approval, e.g. RCP 240, RCP 400 or Others. Enter new line for each approval type.
PBN Approval Type	Enter or select the type of PBN Approval, e.g. RNP 2, RNP 4, RNAV 10 or Others. Enter new line for each approval type.
PBS Approval Type	Enter or select the type of PBS Approval, e.g. RSP 180, RSP 400, or Others. Enter new line for each approval type.
Remarks	Any Remarks

A.1.2 Point of Contact Details for Matters Relating to State Performance-Based Operational Approvals

A.1.2.1 This form should be completed and returned to the address below on the first reply to the designated monitoring organization and when there is a change to any of the details requested on the form. **PLEASE USE BLOCK CAPITALS THROUGHOUT.**

NAME OF STATE AUTHORITY OR ORGANIZATION			
STATE OF REGISTRY			
STATE OF REGISTRY (ICAO 2 letter identifier)			

If there is more than one identifier for the State, please use the first that appears in the list.

ADDRESS DETAILS	
STREET	
CITY	
STATE/PROVINCE	
ZIP/POSTAL CODE	
COUNTRY/REGION	

CONTACT PERSON	
TITLE	
FIRST NAME	
MIDDLE NAME	
LAST NAME	
JOB TITLE	
EMAIL	

PHONE DETAILS			
COUNTRY CODE		AREA CODE	
DIRECT LINE		FAX NUMBER	

When complete, please return to the following address.

Address:

Telephone:

Fax:

Email:

A.1.3 Record of State Performance-Based Operation Approval

A.1.3.1 When a State of Registry approves or amends the approval of an operator/aircraft for State performance-based operations, details of that approval must be recorded and sent to the appropriate organization without delay.

A.1.3.2 Please refer to the accompanying notes on the following page before providing the information requested below. **PLEASE USE BLOCK CAPITALS.**

[illegible]

Remarks	

When complete, please return to the following address.

Address:

Telephone:

Fax:

Email:

Field	Instruction
State of Registry State of Operator State of Performance Based Operation Approval	Enter the 2-letter ICAO identifier as contained in ICAO Doc 7910. In the case of there being more than one identifier designated for the State, use the letter identifier that appears first.
Operator Identifier	Enter the operator's 3 letter ICAO identifier as contained in ICAO Doc 8585. For International General Aviation, enter "IGA". If none, place an X in this field and enter the name of the operator/owner in the Remarks row.
Operator Type	Enter or Select Operator Type. E.g. Civil or Military
Registration Date Date of Approval Date of Expiry	Enter date in dd/mm/yyyy format, e.g. for 26 October 2013 enter 26/10/2013.
Aircraft Type	Enter the ICAO designator as contained in ICAO Doc 8643, e.g., for Airbus A320-211, enter A320; for Boeing B747-438 enter B744.
Aircraft Series	Enter series of aircraft type or manufacturer's customer designation, e.g., for Airbus A320-211, enter 211; for Boeing B747-438, enter 400 or 438.
Mode S Address Code (Hex)	Enter ICAO allocated Aircraft Mode S address code in hexadecimal format.
PBC/PBN/PBS Approval Type	Enter or select the type of PBC/PBN/PBS Approval, e.g. RCP 240, RCP 400, RNP 2, RNP 4, RNAV 10, RSP 180, RSP 400 or Others. Enter new line for each approval type.
Remarks	Any Remarks

A.1.4 Withdrawal of State Performance-Based Operation Approval

A.1.4.1 When a State of Registry has cause to withdraw the State performance-based operation approval of an operator/aircraft, the details requested below must be sent to the designated monitoring organization without delay.

A.1.4.2 Please refer to the accompanying notes on the following page before providing the information requested. **PLEASE USE BLOCK CAPITALS.**

State of Registry																			
Operator Identifier																			
State of Operator																			
Aircraft Type																			
Aircraft Series																			
Manufacturers Serial Number																			
Registration Mark																			
Mode S Address Code (Hex)																			
Approval Withdrawn (PBC/PBN/PBS)																			
Date of Withdrawal																			
PBC/PBN/PBS Withdrawn CAA Official																			
Reason for Withdrawal																			

Fields	Instruction
State of Registry State of Operator	Enter the 2-letter ICAO identifier as contained in ICAO Doc 7910. In the case of there being more than one identifier designated for the State, use the letter identifier that appears first.
Operator Identifier	Enter the operator's 3 letter ICAO identifier as contained in ICAO Doc 8585. For International General Aviation, enter "IGA". If none, place an X in this field and enter the name of the operator/owner in the Remarks row.
Date of Withdrawal	Enter date in dd/mm/yyyy format, e.g. for 26 October 2013 enter 26/10/2013.
Aircraft Type	Enter the ICAO designator as contained in ICAO Doc 8643, e.g., for Airbus A320-211, enter A320; for Boeing B747-438 enter B744.
Aircraft Series	Enter series of aircraft type or manufacturer's customer designation, e.g., for Airbus A320-211, enter 211; for Boeing B747-438, enter 400 or 438.
Mode S Address Code (Hex)	Enter ICAO allocated Aircraft Mode S address code in hexadecimal format.
Approval Withdrawn	Enter or select the type of PBC/PBN/PBS Approval, e.g. RCP 240, RCP 400, RNP 2, RNP 4, RNAV 10, RSP 180, RSP 400 or Others. Enter new line for each approval type.

A.1.5 Letter to State authority requesting clarification of the state performance based operation approval status of an operator

When the State performance based operation approval status shown in filed flight plan is not confirmed in the database of State approvals, a letter similar to the following should be sent to the relevant State authority.

<STATE AUTHORITY ADDRESS>

1. The (monitoring organization name) has been established by the ICAO Asia/Pacific Regional Airspace Safety Monitoring Advisory Group (RASMAg) to support safe implementation and use of the horizontal separation in (airspace where the monitoring organization has responsibility), in accordance with guidance published by the International Civil Aviation Organization.

2. Among the other activities, the (monitoring organization name) conducts a comparison of the State performance based-operation approval status, provided by an operator to an air traffic control unit, to the record of State performance-based operation approval available to us. This comparison is considered vital to ensuring the continued safe use of horizontal separation.

3. This letter is to advise you that an operator which we believe is on your State registry provided notice of State performance-based operation approval which is not confirmed by our records. The details of the occurrence are as follows:

- a) Date:
- b) Operator name:
- c) Aircraft flight identification:
- d) Aircraft type:
- e) Registration mark:
- f) Filed performance based operation approval type:
- g) ATS unit receiving notification:

4 We request that you advise this office of the State performance-based operation approval status of this operator. In the event that you have not granted a State performance-based operation approval to this operator, we request that you advise this office of any action which you propose to take.

Sincerely,

(monitoring organization official)

A.2 Minimal informational content for each state performance-based operation approval to be maintained in electronic form

A.2.1 Aircraft Performance Based Operation Approvals Data

A.2.1.1 To properly maintain and track performance based operation approval information some basic aircraft identification information is required (e.g., manufacturer, type, serial number, etc.) as well as details specific to an aircraft's performance based operation approval status. [Table A- 2](#) below lists the minimum data fields to be collected for an individual aircraft. [Table A- 3](#) on the following page describes the approvals database record format.

Table A- 2. Aircraft Performance Based Operation Approvals Data

Field	Description
Registration Mark	Aircraft's current registration mark
Mode S Address Code (Hex)	Aircraft current Mode S code 6 hexadecimal digits
Manufacturer Serial Number	Aircraft Serial Number as given by manufacturer
Aircraft Type	Aircraft Type as defined by ICAO document 8643
Aircraft Series	Aircraft generic series as described by the aircraft manufacturer (e.g., 747-100, series = 100)
State of Registry	State to which the aircraft is currently registered as defined in ICAO document 7910
Registration Date	Date registration was active for current operator
Operator Identifier	ICAO code for the current Operator as defined in ICAO document 8585
Operator Name	Name of the current Operator
State of Operator	State of the current Operator as defined in ICAO document 7910
Operator Type	Aircraft is civil or military
PBC, PBN and/or PBS approval type	PBC, PBN, and/or PBS approval – e.g. RCP 240, RCP 400, RNP 4, RNAV 2, RNP 1, RSP 180, RSP 400, or others
Region for PBC, PBN and/or PBS approval	Name of region where the PBC/PBN/PBS approval is applicable Note: Only required if PBC/PBN/PBS Approval is issued for a specific region
State of PBC, PBN, and/or PBS approval	State granting PBC, PBN, and/or PBS approval as defined in ICAO document 9613
Date PBC, PBN, and/or PBS approved	Date of PBC, PBN, and/or PBS Approval
Date of PBC, PBN, and/or PBS expiry	Date of Expiry for PBC, PBN, and/or PBS Approval
Date of Data Link approval	Date of Data Link Approval

Field	Description
Remarks	Open comments
Date of withdrawal of PBC, PBN, and/or PBS approval	Date of withdrawal of the aircraft's PBC, PBN, and/or PBS approval (if applicable)
Info by Authority	Yes or no indication "Was the information provided to the monitoring organization by a State Authority?"

Table A-3. Approvals Database Record Format

Field	Description	Type	Width	Valid Range
State of Registry	State of Registry	Alphabetic	2	AA-ZZ
Operator	Operator	Alphabetic	3	AAA-ZZZ
State of Operator	State of Operator	Alphabetic	2	AA-ZZ
AC Type	Aircraft Type	Alphanumeric	4	e.g. MD11
AC Mark/Series	Aircraft Mark / Series	Alphanumeric	6	
Serial Number	Manufacturer's Serial/Construction Number	Alphanumeric	12	
AC Registration Mark	Aircraft registration mark	Alphanumeric	10	
Mode S	Aircraft Mode "S" address (Hexadecimal)	Alphanumeric	6	000001-FFFFFF
PBC approval type	PBC approval type	Alphanumeric	6	e.g. RCP240
PBC approval date	Date PBC approval issued (dd/mm/yyyy)	Date	10	e.g. 31/12/2014
PBC Date of expiry	Date of expiry of PBC approval (if any) (dd/mm/yyyy)	Date	10	e.g. 31/12/2014
PBN approval type	PBN approval type	Alphanumeric	6	e.g. RNP4
PBN Approval Date	Date PBN approval issued (dd/mm/yyyy)	Date	10	e.g. 31/12/2014
PBN Date of expiry	Date of expiry of PBN approval (if any) (dd/mm/yyyy)	Date	10	e.g. 31/12/2014
PBS approval type	PBS approval type	Alphanumeric	6	e.g. RSP180

Field	Description	Type	Width	Valid Range
PBS approval date	Date PBS approval issued (dd/mm/yyyy)	Date	10	e.g. 31/12/2014
PBS Date of expiry	Date of expiry of PBS approval (if any) (dd/mm/yyyy)	Date	10	e.g. 31/12/2014
Remarks	National remarks	Alphanumeric	60	ASCII text

A.2.2 Aircraft Re-Registration/Operating Status Change Data

A.2.2.1 Aircraft frequently change registration information. Re-registration and change of operating status information is required to properly maintain an accurate list of the current population. **Table A- 4** below lists the minimum data fields to be maintained to manage aircraft re-registration/operating status change data.

Table A- 4. Aircraft Re-Registration/Operating Status Change Data

Field	Description
Reason for change	Reason for change. Aircraft was re-registered, destroyed, parked, etc.
Previous Registration Mark	Aircraft's previous registration mark.
Previous Mode S	Aircraft's previous Mode S code.
Previous Operator Name	Previous name of operator of the aircraft.
Previous Operator ICAO Code	ICAO code for previous aircraft operator.
Previous State of Operator	ICAO code for the previous State of the operator
New State of Operator	ICAO code for the State of the current aircraft operator.
New Registration Mark	Aircraft's current registration mark.
New State of Registration	Aircraft's current State of Registry.
New Operator Name	Current name of operator of the aircraft.
New Operator ICAO Code	ICAO code for the current aircraft operator.
Aircraft ICAO Type designator	Aircraft Type as defined by ICAO document 8643
Aircraft Series	Aircraft generic series as described by the aircraft manufacturer (e.g., 747-100, series = 100).
Serial Number	Aircraft Serial Number as given by manufacturer
New Mode S	Aircraft's current Mode S code 6 hexadecimal digits.
Date change is effective	Date new registration/ change of status became effective.

A.2.3 Point of Contact Data

A.2.3.1 An accurate and up to date list of contact officers is essential for the designated monitoring organization to conduct its business. [Table A- 5](#) lists the minimum content for organizational contacts and [Table A- 6](#) lists the minimum content for individual points-of-contact.

Table A- 5. Organizational Contact Data

Field	Description
Type	Type of contact (e.g., Operator, Airworthiness Authority, Manufacturer)
State	State in which the company is located.
State ICAO	ICAO code for the State in which the company is located.
Company/Authority	Name of the company/authority as used by ICAO (e.g., Bombardier)
Fax No	Fax number for the company.
Telephone number	Telephone number for the company.
Address (1-4)	Address lines 1-4 filled as appropriate for the company.
Place	Place (city, etc.) in which the company is located.
Postal code	Postal code for the company.
Country	Country in which the company is located.
Remarks	Open comments
Modification date	Last Modification Date.
Web-site	Company Web HTTP Location.
e-mail	Company e-mail address.
Civ/mil	Civil or Military.

Table A- 6. Individual Point of Contact Data

Field	Description
Title contact	Mr., Mrs., Ms., etc.
Surname contact	Surname or family name of point of contact.
Name contact	Given name of point of contact.
Position contact	Work title of the point of contact.
Company/Authority	Name of the company/authority as used by ICAO (e.g., Bombardier)
Department	Department for the point of contact.
Address (1-4)	Address lines 1-4 filled as appropriate for the point of contact.
Place	Place (city, etc.) in which the point of contact is located.
Postal code	Postal code for the location of the point of contact.
State	State in which the point of contact is located.

Field	Description
Country	Country in which the point of contact is located.
E-mail	E-mail of the point of contact.
Telex	Telex number of the point of contact.
Fax No	Fax number of the point of contact.
Telephone no 1	First telephone number for the point of contact.
Telephone no 2	Second telephone number for the point of contact.

A.2.4 Data Exchange among monitoring organizations

A.2.4.1 General

A.2.4.1.1 The following sections describe how data is to be shared among monitoring organizations as well as the minimum data set that should be passed from one organization that monitors the application of performance-based horizontal separation minima to another monitoring organization of the same type. This minimum sharing data set is a sub-set of the data defined in previous sections of this appendix.

A.2.4.1.2 All organizations receiving data have responsibility to help ensure data integrity. A receiving monitoring organization must report back to the sending monitoring organization any discrepancies or incorrect information found in the sent data.

A.2.4.2 Data Exchange Procedures

A.2.4.2.1 The standard mode of exchange shall be e-mail or FTP, with frequency of submission in accordance with [Table A- 7](#). Data shall be presented in Microsoft Excel or Microsoft Access.

A.2.4.2.2 The monitoring organization must be aware that the data are current only to the date of the created file.

Table A- 7. Monitoring organization data exchange procedures

Data Type	Data Subset	Frequency	When
Performance Based Operation approvals	All	Monthly	First week in month
Aircraft Re-registration/ status	New since last broadcast	Monthly	First week in month
Contact	All	Monthly	First week in month
Non-Compliant Aircraft	All	As Required.	Immediate

A.2.4.2.3 In addition to regular data exchanges, one-off queries shall be made between monitoring organizations, as necessary. This includes requests for data in addition to the minimum exchanged data set such as service bulletin information.

A.2.4.3 Exchange of Aircraft Approvals Data

A.2.4.3.1 Performance based operational approval data shall be exchanged among monitoring organizations. **Table A- 8** below defines the fields required for sending a record to another monitoring organization.

Table A- 8. Exchange of Aircraft Approvals Data

Field	Need to Share
Registration Mark	Mandatory
Mode S	Desirable
Serial Number	Desirable
Aircraft Type	Mandatory
Aircraft Series	Mandatory
State of Registry	Mandatory
Registration date	Desirable
Operator Identifier	Mandatory
Operator Name	Desirable
State of Operator	Mandatory
Civil or military indication (not a field on its own. It is indicated in the ICAO operator code as MIL except when the military has a code)	Desirable
State of PBC, PBN, and PBS approval	Mandatory
PBC approval types	Mandatory
Date PBC approved	Mandatory
Date of PBC approval expiry	Mandatory
PBN approval type	Mandatory
Date PBN approved	Mandatory
Date of PBN approval expiry	Mandatory
PBS approval types	Mandatory
Date PBS approved	Mandatory
Date of PBS approval expiry	Mandatory
Remarks	No
Date of withdrawal of PBC approval	Mandatory

Field	Need to Share
Date of withdrawal of PBN approval	Mandatory
Date of withdrawal of PBS approval	Mandatory
Information by Authority	Mandatory

A.2.4.4 Aircraft Re-Registration/Operating Status Change Data

A.2.4.4.1 All re-registration information as shown in [Table A- 9](#) shall be shared.

Table A- 9. Exchange of Aircraft Re-Registration/Operating Status Change Data

Field	Need to Share
Reason for change (i.e. re-registered, destroyed, parked)	Mandatory
Previous Registration Mark	Mandatory
Previous Mode S	Desirable
Previous Operator Name	Desirable
Previous Operator ICAO Code	Mandatory
Previous State of Operator	Mandatory
State of Operator	Mandatory
New Registration Mark	Mandatory
New State of Registration	Mandatory
New Operator Name	Desirable
New Operator Code	Desirable
Aircraft ICAO Type designator	Mandatory
Aircraft Series	Mandatory
Serial Number	Mandatory
New Mode S	Mandatory
Date change is effective	Desirable

A.2.4.5 Exchange of Contact Data

A.2.4.5.1 All organization and individual point of contact data shall be shared in accordance with Table A- 10 and Table A- 11.

Table A- 10. Exchange of Organizational Contact Data Fields

Field	Need to Share
Type	Mandatory
State	Mandatory
State ICAO	Desirable
Company/Authority	Mandatory
Fax No	Desirable
Telephone number	Mandatory
Address (1-4)	Mandatory
Place	Mandatory
Postal code	Mandatory
Country	Mandatory
e-mail	Desirable
civil/military	Desirable

Table A- 11. Exchange of Individual Point of Contact Data Fields

Field	Need to Share
Title contact	Desirable
Surname contact	Mandatory
Name contact	Desirable
Position contact	Desirable
Company/Authority	Mandatory
Department	Desirable
Address (1-4)	Mandatory
Place	Mandatory
Postal code	Mandatory
Country	Mandatory
State	Mandatory
E-mail	Desirable
Fax No	Desirable
Telephone no 1	Mandatory
Telephone no 2	Desirable

A.2.4.6 Confirmed Non-Compliant Information

A.2.4.6.1 As part of the monitoring assessments, a non-compliant aircraft may be identified. This information should be made available to other monitoring organizations. Information to be included when identifying a non-compliant aircraft are:

- a) Name of the originating monitoring organization;
- b) Date sent;
- c) Registration Mark;
- d) Mode S;
- e) Serial Number;
- f) ICAO Type Designator;
- g) State of Registry;
- h) Registration Date;
- i) Operator ICAO Code;
- j) Operator Name;
- k) State of Operator;
- l) Date(s) of non-compliance(s);
- m) Action started (y/n); and
- n) Date non-compliance resolved.

A.2.4.7 Fixed parameters -Reference Data Sources

A.2.4.7.1 The sources of some standard data formats are as follows:

- a) ICAO Doc 7910 “Location Indicators”;
- b) ICAO Doc 8585 “Designators for Aircraft Operating Agencies, Aeronautical Authorities, and Services”;
- c) ICAO Doc 8643 “Aircraft Type Designators”; and
- d) IATA “Airline Coding Directory”.

Appendix B FORM FOR ATS UNIT MONTHLY REPORT OF LLD OR LLE**[EN-ROUTE MONITORING AGENCY OR GROUP NAME]***Report of Large Lateral Deviation or Large Longitudinal Error*

Report to the (En-route Monitoring Agency or Group Name) of a large lateral deviation (LLD) or a large longitudinal error (LLE), including those due to weather deviations and other contingency events, as defined below:

Type of Error	Category of Error	Criterion for Reporting
Lateral deviation	Individual-aircraft error	Any lateral deviation from the current flight plan track that is greater than a regionally agreed value pertinent to the applied separation minimum
Longitudinal deviation	Aircraft-pair (Time-based separation applied)	Infringement of longitudinal separation standard based on routine position reports
Longitudinal deviation	Aircraft-pair (Time-based separation applied)	Expected time between two aircraft varies by 2 minutes or more based on routine position reports
Longitudinal deviation	Individual-aircraft (Time-based separation applied)	Pilot estimate varies by 2 minutes or more from that advised in a routine position report
Longitudinal deviation	Aircraft-pair (Distance-based separation applied)	Infringement of longitudinal separation standard, based on ADS, radar measurement or special request for RNAV position report
Longitudinal deviation	Aircraft-pair (Distance-based separation applied)	Expected distance between an aircraft pair varies by 6 NM or more, even if separation standard is not infringed, based on ADS, radar measurement or special request for RNAV position report

Name of ATS unit: _____

Please complete Section I or II as appropriate.

SECTION I:

There were no reports of LLDs or LLEs for the month of _____

SECTION II:

There was/were _____ report(s) of LLD

There was/were _____ report(s) of LLE

Details of the LLDs and LLEs are attached.

(Please use a separate form for each report of lateral deviation or longitudinal error).

SECTION III:

When complete please forward the report(s) to:

En-route Monitoring Agency or Group Name

Postal address

Telephone:

Fax:

E-Mail:

NAVIGATION ERROR INVESTIGATION FORM

PART 1 - To be completed by responsible officer in the Service Provider (and aircraft owner/operator if necessary)		
ATC Unit Observing Error:		
Date/Time (UTC):		
Duration of Deviation:		
Type of Error: (tick one) <input type="checkbox"/> LATERAL <input type="checkbox"/> LONGITUDINAL		
Details of Aircraft		
	First Aircraft	Second Aircraft (when longitudinal deviation observed)
Aircraft Identification:		
Name of owner/Operator:		
Aircraft Type:		
Departure Point:		
Destination:		
Route Segment:		
Cleared Track:		
Position where error was observed: (BRG/DIST from fixed point or LAT/LONG)		
Extent of deviation – magnitude and direction: (NM for lateral, min/NM for longitudinal)		
Flight Level:		
Approximated Duration of Deviation (minutes)		
For All Errors		
Action taken by ATC:		
Crew Comments when notified of Deviation:		
Other Comments:		

** (Please Attach ATS Flight Plan)

NAVIGATION ERROR INVESTIGATION FORM

PART 2 - Details of Aircraft, and Navigation and Communications Equipment Fit (To be completed by aircraft owner/operator)			
LRNS	Number of Systems (0, 1, 2 etc.)	Make	Model
INS			
IRS			
GNSS			
FMS			
Others (please Specify)			
COMS			
HF			
VHF			
SATCOM			
CPDLC			
Which navigation system was coupled to the autopilot at the time of observation of the error?			
Which Navigation Mode was selected at the time of observation of the error?			
Which Communication System was in use at the time of observation of the error?			
Aircraft registration and model/series			
Was the aircraft operating according to PBC requirements?		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Was the aircraft operating according to PBN requirements?		<input type="checkbox"/> Yes	<input type="checkbox"/> No
Was the aircraft operating according to PBS requirements?		<input type="checkbox"/> Yes	<input type="checkbox"/> No

NAVIGATION ERROR INVESTIGATION FORM

PART 3 – Detailed description of incident
(To be completed by owner/operator – use separate sheet if required)

Please give your assessment of the actual track flown by the aircraft, and the cause of the deviation:

Corrective action proposed:

PART 4 – To be completed by owner/operator, only in the event of partial or total navigation equipment failure.

Navigation System Type	INS	IRS/FMS	Others (Please specify)
Indicate the number of units of each type which failed			
Indicate position at which failure(s) occurred			
Give an estimate of the duration of the equipment failure(s)			
At what time were ATC advised of the failure(s)?			

NAVIGATION ERROR INVESTIGATION FORM

PART 5 – To be completed by investigating organization		
Have all required data been supplied?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Is further investigation warranted?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Will this incident be the subject of a separate report?	<input type="checkbox"/> Yes	<input type="checkbox"/> No
Description of Error:		
Classification: (please circle) A B C D E F G H I		
CLASSIFICATION OF NAVIGATION ERRORS		
Deviation Code	Cause of Deviation	
Operational Errors		
A	Flight crew deviate without ATC Clearance;	
B	Flight crew incorrect operation or interpretation of airborne equipment (e.g. incorrect operation of fully functional FMS, incorrect transcription of ATC clearance or re-clearance, flight plan followed rather than ATC clearance, original clearance followed instead of re-clearance etc.);	
C	Flight crew waypoint insertion error, due to correct entry of incorrect position or incorrect entry of correct position;	
D	ATC system loop error (e.g. ATC issues incorrect clearance, Flight crew misunderstands clearance message etc);	
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility;	
Deviation due to navigational errors		
F	Navigation errors, including incorrect position estimate or equipment failure of which notification was not received by ATC or notified too late for action;	
Deviation due to Meteorological Conditions		
G	Turbulence or other weather related causes (other than approved);	
Others		
H	An aircraft without PBC/PBN/PBS approval;	
I	Others (Please specify)	

Appendix C SCRUTINY GROUP GUIDANCE

C.1 Composition

C.1.1 The Scrutiny Group requires a diverse set of subject-matter expertise. The Scrutiny Group could consist of subject matter experts in air traffic control, aircraft operation, operational pilot groups, regulation and certification, data analysis, and risk modeling from the involved regions.

C.1.2 If necessary, a working group could be formed to discuss specific subject matters, and might consist of subject matter experts and specialists from member States, designated monitoring organization, data link monitoring agencies etc. The working group would be responsible for executing the preparatory work for a meeting of the Scrutiny Group, including the analysis and categorization of selected LLDs and LLEs.

C.2 Purpose

C.2.1 The purpose of the Scrutiny Group is to examine reports of LLDs and LLEs from the monitoring program with the objective of determining which reports from the monitoring program will influence the risk of collision associated with the horizontal separation. For example, the Scrutiny Group could examine possible LLDs and LLEs affected by the reliability and accuracy of the avionics within the aircraft and/or by external meteorological events and/or by the human element in the development of the safety assessment.

C.2.2 Once the Scrutiny Group has made its initial determination, the data are reviewed to look for performance trends. If any adverse trends exist, the Scrutiny Group may make recommendations to either ANSPs or regulatory authorities for reducing or mitigating the effect of those trends as a part of ongoing horizontal separation safety oversight.

C.3 Process

C.3.1 The primary method employed is to examine existing databases as well as other sources and analyze events resulting in:

- a) Lateral tracking errors based on any lateral deviation from the current flight plan track greater than a regionally agreed value pertinent to the applied separation standard or a lesser value determined by the designated monitoring organization as necessary where lower value PBN specifications are used;
- b) Variations of longitudinal separation of three minutes or more; or
- c) Variations of longitudinal separation of 6 NM or more.

C.3.2 These events are usually the result of operational errors, navigation errors or meteorologically influenced events etc. The largest source of reports useful for these purposes comes from existing reporting systems, such as the reporting system established by regional agreement.

C.3.3 The Scrutiny Group should meet to analyze reports of LLDs and LLEs so that adverse trends can be identified quickly and remedial actions can be taken to ensure that risk due to operational errors has not increased following the implementation of horizontal separation.

C.4 Analysis and Methodology

C.4.1 The working group is tasked to analyse the reports of interest and examine the category assigned to each event. The event categories can be found in [Appendix B](#).

C.4.2 The working group relies on its expert judgment and operational experience to analyse these reports. Upon completion of their preliminary analysis, the Sub-Group will present the results to the Scrutiny Group.

C.4.3 The Scrutiny Group shall examine its working group's analysis results and take follow-up action as required.

Appendix D TRAFFIC SAMPLE DATA (TSD) FOR TRAFFIC MOVEMENTS

This Appendix provides the information required and optionally for each flight in a sample of traffic movements. This information is referred to as traffic sample data (TSD). An example of how this information is used in a “know your airspace” analysis is contained in [Appendix E](#).

INFORMATION FOR EACH FLIGHT IN THE SAMPLE

The information requested for a flight in the sample is listed in the following table with an indication as to whether the information is necessary or is optional:

FIELD	EXAMPLE	MANDATORY OR OPTIONAL
Date (dd/mm/yyyy)	08/05/2007 for 8 May 2007	Mandatory
Aircraft Call Sign	XXX704	Mandatory
Aircraft Registration Mark	VH-ABC	Mandatory
PBC Approval type	RCP 240	Mandatory
PBN Approval type	RNP 4	Mandatory
PBS Approval type	RSP 180	Mandatory
Aircraft Type	B734	Mandatory
Origin Aerodrome	WMKK	Mandatory
Destination Aerodrome	RPLL	Mandatory
Entry Fix into Airspace	MESOK	Mandatory
Time at Entry Fix (UTC)	0225 or 02:25	Mandatory
Flight Level at Entry Fix	330	Mandatory
Assigned Mach number at Entry Fix	M0.77	Optional
Route after Entry Fix		Mandatory
Exit Fix from Airspace	NISOR	Mandatory
Time at Exit Fix (UTC)	0401 or 04:01	Mandatory
Flight Level at Exit Fix	330	Mandatory
Assigned Mach number at Exit Fix	M0.77	Optional
Route before Exit Fix		Mandatory
First Fix Within the Airspace OR First Airway Within the Airspace	MESOK OR G582	Optional
Time at First Fix (UTC)	0225 or 02:25	Optional
Flight Level at First Fix	330	Optional
Route after first fix		Optional

FIELD	EXAMPLE	MANDATORY OR OPTIONAL
Second Fix Within the Airspace OR Second Airway Within the Airspace	MEVAS OR G577	Optional
Time at Second Fix (UTC)	0250 or 02:50	Optional
Flight Level at Second Fix	330	Optional
Route after second fix		Optional
(Continue with as many Fix/Time/Flight-Level/Route entries as are required to describe the flight's movement within the airspace)		Optional

Appendix E EXAMPLE “KNOW YOUR AIRSPACE” ANALYSIS

Examination of Operations conducted on South China Sea - RNAV routes L642 and M771

E.1 Introduction

E.1.1 This appendix is an example of a “Know Your Airspace” analysis. It shows how the characteristics of ATS routes L642 and M771 airspace analysis, derived from the traffic movement data collected during December 2007 and other sources, could support the safety assessment on the implementation of the horizontal separation minima.

E.2 Background

E.2.1 As the result of APANPIRG agreement, traffic movement information is collected each December from all Asia/Pacific Region flight information regions (FIRs) within which the Reduced Vertical Separation Minimum (RVSM) is applied. The traffic movement sample is termed the Traffic Sample Data (TSD). The TSD contains information for each flight operating in RVSM airspace during the month:

E.2.2 These data contribute to the conduct of an annual assessment of the safety of continued RVSM use. With proper treatment, these data are also useful to support assessment of the safety of lateral and longitudinal separation minima. The information required and optionally for each flight in a sample of traffic movements is contained in [Appendix D](#).

E.2.3 Four FIRs – Ho Chi Minh, Hong Kong, Sanya and Singapore – have air traffic control responsibility for L642 and M771. Records of all flights operating on L642 and M771 from each of the four TSDs were merged through a software process to avoid duplicate counting of flights. The resulting combined TSD was compared to the TSD from each FIR in order to check for flights missing from individual TSDs but reported in others, and for agreement of times at fixes common to two TSDs. These and other consistency checks led to the conclusion that the quality of data-entry in each of the TSD samples was very high, and that, as a consequence, the combined December 2007 TSD provided a highly reliable basis for gaining insight into the airspace characteristics of flight operations on L642 and M771.

E.2.4 After processing and merging, a total of 5743 flight operations were observed on L642 and M771 during December 2007.

E.3 Characteristics of L642 and M771

E.3.1 Operator Profile

E.3.1.1 Flights operating on L642 and M771 in the combined December 2007 TSD were examined to identify and quantify several important characteristics of airspace use. Principal among these are the profile of operators using the routes, the aircraft types observed on the routes, the origin-destination aerodrome pairs for operations, flight level use on the routes and the operator/aircraft-type pairs seen to have used L642 or M771.

E.3.1.2 Each traffic movement was examined to determine the operator conducting the flight. A total of 61 unique three-letter ICAO operator designators were observed in the merged TSD. [Table E- 1](#)

presents the top 25 of these operator-designator counts, which account for nearly 97 percent of the operations. As will be noted, the top four operators account for nearly half of the operations, while the top 10 account for about three operations in four.

Table E- 1. Top 25 Operator Designators Observed in Combined December 2007 TSD

Number	Operator	Count	Proportion	Cumulative Count	Cumulative Proportion
1	SIA	1045	0.1820	1045	0.1820
2	CPA	839	0.1461	1884	0.3281
3	AXM	439	0.0764	2323	0.4045
4	MAS	393	0.0684	2716	0.4729
5	CES	334	0.0582	3050	0.5311
6	CSN	328	0.0571	3378	0.5882
7	TGW	327	0.0569	3705	0.6451
8	CCA	248	0.0432	3953	0.6883
9	CXA	191	0.0333	4144	0.7216
10	GIA	159	0.0277	4303	0.7493
11	SLK	157	0.0273	4460	0.7766
12	CAL	142	0.0247	4602	0.8013
13	SQC	139	0.0242	4741	0.8255
14	HVN	139	0.0242	4880	0.8497
15	JSA	125	0.0218	5005	0.8715
16	UAL	99	0.0172	5104	0.8887
17	CSZ	97	0.0169	5201	0.9056
18	HKE	62	0.0108	5263	0.9164
19	SHQ	58	0.0101	5321	0.9265
20	AHK	46	0.0080	5367	0.9345
21	TSE	42	0.0073	5409	0.9418
22	CRK	41	0.0071	5450	0.9490
23	VVM	39	0.0068	5489	0.9558
24	KAL	31	0.0054	5520	0.9612
25	CSH	31	0.0054	5551	0.9666

E.3.1.3 A total of 37 unique ICAO four-letter aircraft-designators were found in the combined December 2007 TSD. Inspection of the data showed that less than one-half of one percent of December 2007 operations on L642 and M771 were conducted by either international general aviation (IGA) or

State aircraft. The top 15 aircraft types, accounting for 97 percent of the December 2007 operations, are shown in [Table E- 2](#).

Table E- 2. Top 15 Aircraft-Type Designators Observed in Combined December 2007 TSD

Number	Type	Count	Proportion	Cumulative Count	Cumulative Proportion
1	A320	1083	0.1886	1083	0.1886
2	B772	900	0.1567	1983	0.3453
3	A333	791	0.1377	2774	0.4830
4	B773	557	0.0970	3331	0.5800
5	B738	554	0.0965	3885	0.6765
6	B744	465	0.0810	4350	0.7574
7	A319	314	0.0547	4664	0.8121
8	A306	148	0.0258	4812	0.8379
9	B737	147	0.0256	4959	0.8635
10	A321	145	0.0252	5104	0.8887
11	B752	125	0.0218	5229	0.9105
12	B742	108	0.0188	5337	0.9293
13	MD11	90	0.0157	5427	0.9450
14	B763	82	0.0143	5509	0.9593
15	A343	62	0.0108	5571	0.9701

E.3.1.4 Application of 50 NM longitudinal separation requires availability of Direct Controller-Pilot Communication (DCPC). In previous applications of 50 NM longitudinal separation within the Asia/Pacific Region, this requirement has been satisfied through direct high frequency radio communication between pilots and controllers, as well as through availability of controller-pilot data link communications (CPDLC) and the contract mode of automatic dependent surveillance (ADS-C).

E.3.1.5 As can be seen from [Table E- 2](#), the most frequently occurring aircraft type, the A320, accounts for nearly 19 percent of the operations. The DCPC requirement for operations of this aircraft type will likely need to be satisfied by other than CPDLC or ADS-C. The A320 are not known to be among those aircraft types equipped with either CPDLC or ADS-C. Likewise, types 5, 7, 8, 9, 10, 11, 12 and 14 (B738, A319, A306, B737, A321, B757, B742 and B763, respectively) – which account for an additional 19 percent of the operations in the December 2007 sample – are not known to be equipped, typically, with these technologies.

E.3.2 Origin-Destination Aerodromes

E.3.2.1 A total of 46 aerodromes appeared as either origins or destinations of flights in the combined December 2007 TSD. These aerodromes gave rise to a total of 106 origin-destination pairings.

E.3.2.2 The top 20 origin-destination pairs, in terms of operations, are shown in [Table E- 3](#). As can be seen from the table, nearly one in five operations flew between Singapore Changi Airport and Hong Kong International Airport.

Table E- 3. Top 20 Origin-Destination Pairs Observed in Combined December 2007 TSD

Number	Origin/ Destination	Count	Proportion	Cumulative Count	Cumulative Proportion
1	WSSS VHHH	549	0.0956	549	0.0956
2	VHHH WSSS	509	0.0886	1058	0.1842
3	ZSPD WSSS	297	0.0517	1355	0.2359
4	WSSS ZSPD	271	0.0472	1626	0.2831
5	VHHH WMKK	221	0.0385	1847	0.3216
6	WMKK VHHH	207	0.0360	2054	0.3577
7	VVTS WSSS	177	0.0308	2231	0.3885
8	ZBAA WSSS	174	0.0303	2405	0.4188
9	WSSS ZBAA	174	0.0303	2579	0.4491
10	ZSPD WMKK	159	0.0277	2738	0.4768
11	WSSS ZSAM	156	0.0272	2894	0.5039
12	VHHH VVTS	143	0.0249	3037	0.5288
13	WMKK ZSPD	142	0.0247	3179	0.5535
14	WSSS ZGGG	133	0.0232	3312	0.5767
15	VMMC WMKK	130	0.0226	3442	0.5993
16	ZGGG WSSS	128	0.0223	3570	0.6216
17	WMKK VMMC	127	0.0221	3697	0.6437
18	VHHH WIII	124	0.0216	3821	0.6653
19	WIII VHHH	119	0.0207	3940	0.6861
20	ZSAM WSSS	115	0.0200	4055	0.7061

E.3.3 Use of the RNAV Routes

E.3.3.1 [Table E- 4](#) shows use of the two routes in the combined December 2007 TSD. As can be seen, the proportion of operations on the two routes is not balanced.

Table E- 4. Count of Operations on L642 and M771

Number	Route	Count	Proportion	Cumulative Count	Cumulative Proportion
1	L642	3067	0.5340	3067	0.5340
2	M771	2676	0.4660	5743	1.0000

E.3.4 Flight-Level Usage on L642 and M771

E.3.4.1 **Table E- 5** below presents the flight levels (FLs) and associated frequencies observed in the traffic sample. As can be seen, in order of use, FLs 360, 380 and 340 are the preferred altitudes on the routes, and account for 77 percent of the operations. The one observation at FL220 is very likely due to a minor error in data transcription or interpretation.

Table E- 5. Flight-Level Use on L642 and M771

Number	FL	Count	Proportion	Cumulative Count	Cumulative Proportion
1	360	1738	0.3026	1738	0.3026
2	380	1442	0.2511	3180	0.5537
3	340	1244	0.2166	4424	0.7703
4	400	565	0.0984	4989	0.8687
5	320	459	0.0799	5448	0.9486
6	390	93	0.0162	5541	0.9648
7	300	90	0.0157	5631	0.9805
8	310	36	0.0063	5667	0.9868
9	410	29	0.0050	5696	0.9918
10	330	24	0.0042	5720	0.9960
11	370	9	0.0016	5729	0.9976
12	350	7	0.0012	5736	0.9988
13	290	6	0.0010	5742	0.9998
14	220	1	0.0002	5743	1.0000

E.3.5 Operator/Aircraft-Type Combinations

E.3.5.1 In all, 107 combinations of operator and aircraft type were observed in the combined December 2007 TSD. The top 21 such combinations, accounting for 70 percent of the operations, are shown in **Table E- 6**, with both the operator and aircraft type designations shown in standard ICAO

notation. The knowledgeable reader can determine readily those combinations likely to be equipped with CPDLC and ADS-C.

Table E- 6. Top 21 Operator/Aircraft-Type Combinations Observed in Combined December 2007 TSD

Pair Number	Operator-Aircraft Type	Count	Proportion	Cumulative Count	Cumulative Proportion
1	SIA-B772	611	0.1064	611	0.1064
2	AXM-A320	439	0.0764	1050	0.1828
3	CPA-A333	336	0.0585	1386	0.2413
4	TGW-A320	327	0.0569	1713	0.2983
5	SIA-B773	312	0.0543	2025	0.3526
6	CPA-B773	245	0.0427	2270	0.3953
7	MAS-A333	193	0.0336	2463	0.4289
8	CXA-B737	144	0.0251	2607	0.4539
9	SQC-B744	139	0.0242	2746	0.4781
10	JSA-A320	125	0.0218	2871	0.4999
11	CES-A333	124	0.0216	2995	0.5215
12	CES-A319	122	0.0212	3117	0.5427
13	SIA-B744	122	0.0212	3239	0.5640
14	CSN-A320	103	0.0179	3342	0.5819
15	MAS-B772	103	0.0179	3445	0.5999
16	UAL-B744	99	0.0172	3544	0.6171
17	CSN-A319	99	0.0172	3643	0.6343
18	CSZ-B738	97	0.0169	3740	0.6512
19	CPA-B772	95	0.0165	3835	0.6678
20	SLK-A319	93	0.0162	3928	0.6840
21	GIA-B738	92	0.0160	4020	0.7000

E.4 Summary

E.4.1 The above reviews the Top 25 operators, Top 15 aircraft types, Top 20 origin-destination pairs, flight level use and Top 21 operator/aircraft-type combinations observed in the TSDs in light of the planned introduction of 50 NM lateral and longitudinal separation standards on L642 and M771. Using published information about data link use in other portions of Asia/Pacific Region airspace, this analysis notes the possible aircraft types and operators which might qualify for application of the horizontal separation minima.

DRAFT

Appendix F OVERVIEW OF PERFORMANCE BASED HORIZONTAL COLLISION RISK MODELLING ASSUMPTIONS

The purpose of this appendix is to summarize the collision risk modeling assumptions used in the development of the performance based horizontal separation minima established for oceanic and remote continental navigation applications.

F.1 Longitudinal Collision Risk Model

F.1.1 General

F.1.1.1 The longitudinal model developed for the distance-based separation minima in an RNP RNAV environment using ADS-C and lateral separation of aircraft on parallel or non-intersecting tracks or ATS routes defined is:

$$CR(t_0, t_1) = 2NP \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{t_0}^{t_1} HOP(t | V_1, V_2) P_z(h_z) \left(\frac{2V_{rel}}{\pi\lambda_{xy}} + \frac{|\vec{z}|}{2\lambda_z} \right) f_1(V_1) f_2(V_2) dt dV_1 dV_2 \quad (1)$$

F.1.1.2 The horizontal overlap probability (HOP) term in equation (1) considers the along-track and cross-track position errors of two longitudinally separated aircraft. An equation for operations on the same identical track (e.g. angle of zero degrees) is given in Appendix 1 of ICAO Doc 9689 as:

$$HOP(t | V_1 V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2} e^{-|D_x(t)|/\lambda} \left(\frac{|D_x(t)|}{\lambda} + 1 \right) \quad (2)$$

F.1.1.3 In equation (2), $D_x(t)$ is the distance between the two aircraft and λ is the scale parameter of the along track and cross track error distributions. The along track and cross track errors are assumed to follow a double exponential distribution. See the navigation performance section below for more details.

F.1.1.4 Key parameters for this model are listed in [Table F- 1](#).

Table F- 1. Distance based longitudinal risk model – key parameters

Parameter	Description	Units	Default Value
λ_v	Scale parameter for the aircraft speed distribution, represents the speed decay	Knots	5.82
V_m	Maximum speed variation allowed	Knots	100
S_x	Longitudinal Separation Standard	NM	30, 50

Parameter	Description	Units	Default Value
RNP	Required Navigation Performance Type	NM	4
ONP	Observed navigation performance	NM	
τ	Controller intervention buffer, response time	Seconds	240 for normal cases, 630 and 810 for abnormal cases
T	Aircraft position report interval, ADS-C periodic report rate	Minutes	10, 14, 27
V_1, V_2	Nominal aircraft speeds	Knots	480
$ \dot{z} $	Average absolute relative vertical speed of an aircraft pair that have lost all vertical separation (e.g. vertical speed variation)	Knots	1.5
$P_z(0)$	Probability that two aircraft which are nominally at the same flight level are in vertical overlap		0.55
λ_{xy}	Aircraft wingspan or length	NM	
λ_z	Aircraft height	NM	
NP	Number of pairs that require controller intervention per flight hour	Per flight hour	

F.1.2 Controller intervention buffer

F.1.2.1 ATC to pilot communication times

F.1.2.1.1 There are assumed transaction times for ATC-to-pilot messages in the distance-based longitudinal collision risk model. The message transaction times associated with each type of communication; controller-pilot data link communication (CPDLC) and high frequency (HF), as part of the controller intervention buffer are as follows:

F.1.2.1.2 The time allocated for a CPDLC uplink transaction is 90 seconds

F.1.2.1.3 The time allocated for the controller to wait for the CPDLC response from the pilot is 90 seconds

F.1.2.1.4 The time allocated for ATC to use HF communication to deliver the clearance message is 300 seconds

F.1.2.1.5 The time allocated for ATC to wait for an ADS-C or waypoint change event report is 180 seconds, if the report is not received within 180 seconds of the time it should have been sent, the report is considered overdue.

F.1.2.1.6 Data link performance data from the appropriate data link Central Reporting Agencies (CRAs), FANS Interoperability Team (FIT), NAT Data Link Monitoring Agency (DLMA), or air navigation service providers (ANSPs) should be monitored and utilized to ensure that the communication performance meets these assumptions prior to implementation. Post-implementation monitoring activities should include periodic checks on the communication performance to ensure that the assumptions continue to be valid for the airspace. The observed communication performance may be substituted in place of the assumed performance to obtain an estimate of risk specific to the airspace.

F.1.2.2 Controller intervention buffer scenarios

F.1.2.2.1 The longitudinal distance-based collision risk model developed for an RNP RNAV environment using ADS includes a controller intervention buffer. This is the time to allow a controller to intervene and resolve a potential conflict by contacting an aircraft using the available communication systems. The collision risk modeling considered three cases as described in ICAO Doc 9689 Appendix; normal operation, pilot response to CPDLC is not received requiring HF communication, and ADS-C or waypoint change event report is overdue.

F.1.2.2.2 In case 1, normal operations, the controller intervention buffer time is 240 seconds or 4 minutes. Should the normal means of communication fail, case 2 provides an additional 6.5 minutes using alternative means of communication for controller intervention. If a report is not received within 6 minutes from the time the original report should have been sent, case 3 provides a total of 13.5 minutes for the conflict to be resolved.

F.1.2.2.3 The collision risk model parameter used to indicate the controller intervention buffer is τ . The three cases considered for τ ; normal ADS operation, pilot response to CPDLC is not received requiring HF communication, and ADS-C periodic report is overdue are detailed in [Table F- 2](#) through [Table F- 4](#).

Table F- 2. Components of τ for normal ADS operations

Component	Value (seconds)
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink	90
Pilot reaction	30
Aircraft inertia plus climb	75
Total	240

Table F- 3. Components of τ when response to CPDLC uplink is not received requiring HF communication

Component	Value (seconds)
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink and wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Total	630

Table F- 4. Components of τ when ADS-C periodic report takes longer than 3 minutes

Component	Value (seconds)
Controller wait for ADS report	180
Controller message composition	15
CPDLC uplink and wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Extra allowance	30
Total	810

F.1.2.2.4 The collision risk calculations were carried out assuming that an ADS-C or waypoint change event report is overdue 5 percent of the time (case 3). When ADS or waypoint change event reports are received within 3 minutes, the CPDLC response will take longer than 3 minutes 5 percent of the time (case 2). It was also assumed that normal operations occur 95 percent of the time (case 1). The 5 percent lateness allowance was considered to be very conservative. The weighted risk estimates based on the three cases is:

$$\text{weighted risk} = 0.95 \times (0.95 \times \text{risk}(\tau = 4) + 0.05 \times \text{risk}(\tau = 10.5)) + 0.05 \times \text{risk}(\tau = 13.5)$$

F.1.2.2.5 The proportions in the weighted risk may be modified based on the observed performance in the airspace. Additional cases can also be included in the weighted risk equation for use in a safety assessment to account for the risk associated with specific large longitudinal events (LLEs); care must be taken to ensure the individual proportions add up to one.

F.1.3 Navigation performance

F.1.3.1 Use of the observed navigation performance (ONP) for longitudinal risk estimation is considered to be conservative due to the highly accurate results obtained from the use of Global Navigation Satellite Systems (GNSS). However, the collision risk models originally developed to support the distance-based longitudinal separation minima use the RNP specification and not an observed navigation performance to model the lateral path keeping performance.

F.1.3.2 The accurate position estimates from GNSS produce smaller lateral errors from course and lower across track velocities. Smaller lateral errors produce higher values of lateral overlap probability, thus increasing the risk of collision in the event that airplanes lose their assigned longitudinal separation. This “navigation paradox” – improvements in navigation in one dimension increase collision risk in another – is well known. Its presence in the application of a reduced longitudinal separation minimum is evident in the risk estimates.

F.1.3.3 A DE distribution is used to model the along track and across track position errors in the distance-based longitudinal collision risk model. The observed navigation performance for GNSS aircraft has been modeled with various scale parameters, λ . For example, $k = 0.05, 0.1, 0.3, 0.5, 1$, and 2 have been employed to compute $\lambda = -\frac{k}{\ln(0.05)}$. The parameter λ is chosen to satisfy the requirement $\int_{-\infty}^{\infty} f(y)dy = 0.95$, which states that these RNP aircraft are expected to have position errors less than k NM in magnitude during 95% of their flight time. The value for k is chosen to be lower than the RNP specification due to the very accurate GNSS positions.

F.1.4 Variation in aircraft speed

F.1.4.1 The longitudinal distance-based collision risk model developed for an RNP RNAV environment using ADS accounts for variation in aircraft speed during a time period. This time period is the time between consecutive position reports and the time allotted for the controller intervention buffer.

F.1.4.2 The speed variation follows a DE distribution with scale parameter $\lambda_v = 5.82$ knots. The assumed average aircraft ground speed of 480 knots is used as the location parameter, V_o . The DE distribution is truncated at 100 knots on either side of the location parameter, 480 knots, and then normalized to equal one.

$$f_{DE}(V) = \frac{1}{2\lambda_v} e^{-\frac{|V-V_o|}{\lambda_v}} \text{ for } -100 < V < 100$$

F.1.4.3 The empirical speed variations can be observed in the airspace and used to modify the scale parameter, location parameter or truncation limits. Care must be taken to ensure that the resulting speed variation distribution is suitable for all the appropriate time periods. The time period is equal to the aircraft reporting period plus the allotted time for the controller intervention buffer. It is possible to have multiple aircraft speed variation distributions for use in the collision risk modeling as aircraft speed can be expected to vary greatly over long time periods.

F.2 Lateral collision risk model

F.2.1 General

F.2.1.1 The form of the lateral collision risk model applicable to assessing the risk, N_{ay} , of a 30-NM lateral separation standard from Appendix 15 of ICAO Doc 9689 is:

$$N_{ay} = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}\left\{E_y(\text{same})\left[\frac{|\bar{x}|}{2\lambda_x} + \frac{|\bar{y}(S_y)|}{2\lambda_y} + \frac{|\bar{z}|}{2\lambda_z}\right] + E_y(\text{opp})\left[\frac{|\bar{V}|}{\lambda_x} + \frac{|\bar{y}(S_y)|}{2\lambda_y} + \frac{|\bar{z}|}{2\lambda_z}\right]\right\} \quad (3)$$

F.2.1.2 where the individual parameters of the lateral collision risk model and their definitions are given in [Table F- 5](#).

Table F- 5. Lateral collision risk model – key parameters

Parameter	Description	Units	Default Value
S_y	Lateral Separation Standard	NM	30, 50
RNP	Required Navigation Performance Type	NM	4, 10
$ \bar{z} $	Average absolute relative vertical speed of an aircraft pair that have lost all vertical separation (e.g. vertical speed variation)	Knots	1.5
$P_z(0)$	Probability that two aircraft which are nominally at the same flight level are in vertical overlap		0.55
$P_y(S_y)$	Probability that two aircraft which are nominally separated by the lateral separation minimum are in lateral overlap		Determined from the RNP requirement and the observed frequency of lateral errors in the airspace
λ_x	Aircraft length	NM	
λ_y	Aircraft wingspan	NM	
λ_z	Aircraft height	NM	
$E_y(\text{same})$	Same direction lateral occupancy		
$E_y(\text{opp})$	Opposite direction lateral occupancy		
S_x	Length of longitudinal window used to calculate occupancy	Minutes	15
$ \bar{V} $	Average absolute aircraft speed	Knots	480

Parameter	Description	Units	Default Value
$\overline{ \dot{y}(S_y) }$	Average absolute relative cross track speed	Knots	
$\overline{ \dot{x} }$	Average absolute relative along track speed between aircraft on same direction routes	Knots	

F.2.1.3 Some of the parameters listed in [Table F- 5](#) are common to both the lateral and longitudinal collision risk models.

F.2.2 Lateral path keeping performance, $P_y(S_y)$

F.2.2.1 The RNP specification combined with reports of gross lateral errors (if available) provide a conservative estimate of the lateral overlap probability, $P_y(S_y)$.

F.2.2.2 The typical and atypical lateral deviations are modeled with $f_{core}(y)$ and $f_{tail}(y)$, respectively. The overall density function of the lateral deviations is modeled by the mixture $f(y) = (1-\alpha)f_{core}(y) + \alpha f_{tail}(y)$, with α as the rate of atypical deviations.

F.2.2.3 The choice of a Double Exponential (DE) distribution for the distribution $f_{tail}(y)$ of atypical deviations and $f_{core}(y)$ is considered to be conservative. The density f_{DE} associated with a DE distribution is given by:

$$f_{DE}(y) = \frac{1}{2\lambda} e^{-\frac{|y|}{\lambda}} \text{ for } -\infty < y < \infty$$

F.2.2.4 The typical lateral deviations for RNP k (for example RNP 4, where $k=4$) are modeled as:

$$f(y) = \frac{1}{2\lambda} e^{-\frac{|y|}{\lambda}} \text{ with } \lambda = -\frac{k}{\ln(0.05)}$$

F.2.2.5 The parameter λ is chosen to satisfy the requirement $\int_{-\infty}^{\infty} f(y) dy = 0.95$, which states that RNP k aircraft are expected to have position errors less than k NM in magnitude during 95% of their flight time.

F.2.3 Average absolute relative along-track speed of two aircraft, $\overline{|\dot{x}|}$

F.2.3.1 Aircraft operations on parallel tracks are independent of application of Mach number technique or any other actions by ATC to regulate the relative speed between aircraft. As a result, the relative speed between a typical pair of co-altitude aircraft on adjacent tracks reflects the range of speeds of individual aircraft in the airspace.

F.2.3.2 The reported ground speeds can be examined from the ADS-C basic reports. Using the uncorrelated-speed property of aircraft assigned to the same flight level on parallel routes, the absolute value of each possible difference in speed can be weighted according to the proportions of entries.

F.2.4 Average absolute relative cross-track speed between aircraft pairs operating on tracks nominally separated by $S_y - |\dot{y}(S_y)|$

F.2.4.1 This parameter describes the relative speed of two aircraft as they lose all planned lateral separation. Since the basic track-keeping accuracy of aircraft equipped with navigation systems using GNSS-derived positioning is widely regarded as precluding the loss of 30-NM lateral separation due to normal navigational performance, the most reasonable circumstance associated with an event is a waypoint insertion error. While there are safeguards against the occurrence of this type of event such as the establishment of a 5-NM lateral deviation event contract for all aircraft capable of participating in the application of the 30-NM separation minimum. For example, a value of 36 knots corresponds to the lateral speed of an aircraft relative to correct track, which would result in a lateral error of 30-NM between two consecutive waypoints separated by a typical distance of 400-NM. The assumed average aircraft speed used was 480 knots.

F.2.5 Same and opposite direction lateral occupancy – $E_y(\text{same})$ and $E_y(\text{opp})$

F.2.5.1 Occupancy is a measure of exposure of aircraft to one another. While occupancy does generally increase as traffic level increases, there is not a one-to-one correspondence between a measure of traffic activity – number of annual flights, for example – and the value of airspace occupancy. Rather, occupancy increases as more aircraft operate at the same time on the laterally adjacent flight paths, increasing the chance that there might be a proximate aircraft.

F.2.5.2 Occupancy is a dimensionless number, computed, in the lateral case, as twice the ratio of the number of aircraft on a track which are within an arbitrary longitudinal sampling interval of a typical aircraft on a laterally adjacent track. Lateral occupancy is estimated separately for aircraft flows operating in the same direction on each of two parallel tracks and for flows operating on reciprocal headings on the tracks – hence the terms “same-direction” and “opposite-direction” lateral occupancies.

F.2.5.3 The lateral occupancy can be estimated from traffic movement data. A lateral pair is identified using an aircraft position report when another aircraft crosses over the adjacent fix located on a parallel route separated by the lateral separation minimum.

Appendix G EXAMPLE SAFETY ASSESSMENT - SOUTH CHINA SEA COLLISION RISK MODEL AND SAFETY ASSESSMENT

G.1 Introduction

G.1.1 The South East Asia Safety Monitoring Agency (SEASMA), an En-route Monitoring Agency (EMA), is responsible for supporting continued safe use of the six major air traffic service routes in South China Sea international airspace. This support consists of discharging the EMA duties listed in the Asia/Pacific En-route Monitoring Agency Handbook.

G.1.2 The purpose of this appendix is to present an example of a safety assessment, as conducted by SEASMA on the six major South China Sea routes, together with the collision risk model used, to assess compliance with APANPIRG-agreed Target Level of Safety (TLS) values for the maintenance of lateral and longitudinal separation standards. The examination period covered is 1 January 2013 through 31 December 2013.

G.2 Background

G.2.1 The six South China Sea routes – L642, M771, N892, L625, N884 and M767 – were introduced in November 2001 in order to relieve congestion in the airspace. At the same time, State approval for Required Navigation Performance 10 (RNP 10) (now RNAV 10 under Performance Based Navigation (PBN) terminology) became mandatory for operation at or above flight 290 (FL 290).

G.2.2 This performance requirement was the basis for employing a minimum lateral separation standard of 60NM between-route centerlines. As shown in [Table G- 1](#), the six routes are organized into three route-pairs to serve principal origin destination points, no pre-departure clearance (No-PDC) flight levels by route and some information about routes crossing the RNAV routes.

Table G- 1. Characteristics of Air Traffic Service Routes in South China Sea

Route	Principal Service	Direction of Flow	No-PDC Flight Levels
RNAV L642	Hong Kong/Singapore-Kuala Lumpur	Northeast-southwest	310, 320, 350, 360, 390 and 400
RNAV M771	Singapore-Kuala Lumpur /Hong Kong	Southwest-northeast	Same as L642
RNAV N892	Northeast Asia-Taiwan/Singapore	Northeast-southwest	Same as L642
RNAV L625	Singapore /Northeast Asia-Taiwan	Southwest-northeast	Same as L642
RNAV N884	Singapore /Manila	Southwest-northeast	Same as L642
RNAV M767	Manila/Singapore	Northeast-southwest	Same as L642
Crossing Routes	Various	Bidirectional	Dependent upon route

G.2.3 The longitudinal separation minimum published for the six routes in November 2001 was 10 minutes with Mach Number Technique (MNT), or 80NM RNAV.

G.2.4 Radar monitoring of horizontal navigational performance was initiated with introduction of the RNAV routes. The enabling Letter of Agreement (LOA) – signed by China, Hong Kong China, Indonesia, Malaysia, Singapore, Thailand, Vietnam, and Philippines – specified details concerning the categories of errors to be monitored and reported to Singapore on a monthly basis. The LOA also called for reporting associated counts of flights monitored.

G.2.5 In anticipation of horizontal separation changes being pursued by the ICAO South-East Asia RNP Task Force (RNP-SEA/TF), the LOA was revised in 2008 to formalize certain monitoring activities which had been carried out previously on an informal basis. [Table G-2](#) indicates the fixes where monitoring is taking place under the revised LOA.

Table G- 2. Monitored Fixes in South China Sea Airspace

Route	Fixes	Monitoring Authority
L642	ESPOB to ENREP	Singapore
M771	DULOP and DUMOL	Hong Kong, China
N892	MELAS and MABLI	Singapore
L625	AKOTA and AVMUP	Philippines
N884	LULBU and LEGED	Philippines
M767	TEGID to BOBOB	Singapore

G.2.6 Since adoption of the original LOA, all instances of certain types of lateral and longitudinal errors have been reported to Singapore. The specifics of error-reporting are shown in [Table G-3](#). As will be noted, monitoring systems include automatic dependent surveillance – contract (ADS-C) and position reports, in addition to radar.

Table G- 3. Reporting Criteria for South China Sea Monitoring Programme

Type of Error	Category of Error	Criterion for Reporting
Lateral deviation	Individual-aircraft error	15NM or greater magnitude
Longitudinal deviation	Aircraft-pair (Time-based separation applied)	Infringement of longitudinal separation standard based on routine position reports
Longitudinal deviation	Aircraft-pair (Time-based separation applied)	Expected time between two aircraft varies by 3 minutes or more based on routine position reports

Type of Error	Category of Error	Criterion for Reporting
Longitudinal deviation	Aircraft-pair (Time-based separation applied)	Pilot estimate varies by 3 minutes or more from that advised in a routine position report
Longitudinal deviation	Aircraft-pair (Distance-based separation applied)	Infringement of longitudinal separation standard, based on ADS, radar measurement or special request for RNAV position report
Longitudinal deviation	Aircraft-pair (Distance-based separation applied)	Expected distance between an aircraft pair varies by 10NM or more, even if separation standard is not infringed, based on ADS, radar measurement or special request for RNAV position report

G.2.7 The monitoring criteria in [Table G- 3](#) were chosen to support eventual work by the RNP-SEA/TF to introduce performance based separation standards, specifically RNAV 10 based 50 NM lateral and longitudinal separation and RNP 4 based 30 NM lateral and longitudinal separation. On 2 July 2008, the first of these separation reductions was introduced: the lateral separation standard between L642 and M771 was changed to 50NM and the preferred basis for longitudinal separation on these routes was changed to distance from time, with the minimum longitudinal separation standard between co-altitudes pairs reduced to 50NM.

G.3 Results of Data Collection

G.3.1 The fidelity of large-error and traffic-count reporting by each responsible air navigation service provider (ANSP) for the period Jan 2013 through Dec 2013 is shown in [Table G- 4](#).

Table G- 4. Record of ANSP Reporting by Month for Period January 2013 through December 2013

Month	Report received from:		
	Hong Kong, China	Philippines	Singapore
January 2013	Yes	Yes	Yes
February 2013	Yes	Yes	Yes
March 2013	Yes	Yes	Yes
April 2013	Yes	Yes	Yes
May 2013	Yes	Yes	Yes
June 2013	Yes	Yes	Yes
July 2013	Yes	Yes	Yes
August 2013	Yes	Yes	Yes
September 2013	Yes	Yes	Yes
October 2013	Yes	Yes	Yes

Month	Report received from:		
	Hong Kong, China	Philippines	Singapore
November 2013	Yes	Yes	Yes
December 2013	Yes	Yes	Yes

G.3.2 The total traffic counts reported by month transiting all South China Sea monitoring fixes for the January 2013 through December 2013 monitoring period is shown in [Table G- 5](#).

Table G- 5. Monthly Count of Monitored Flights Operating on South China Sea RNAV Routes

Monitoring Month	Total Monthly Traffic Count Reported Over Monitored Fixes	Cumulative 12-Month Count of Traffic Reported Over Monitored Fixes Through Monitoring Month
January 2013	9983	119637
February 2013	9666	119916
March 2013	10733	120590
April 2013	10711	121297
May 2013	11147	122159
June 2013	10744	122891
July 2013	10767	123458
August 2013	10824	124060
September 2013	10272	124350
October 2013	11139	125190
November 2013	10689	125633
December 2013	11484	126358

G.3.3 The cumulative totals of reported large lateral deviations (LLDs) and large longitudinal errors (LLEs) for the period January 2013 through December 2013 is shown in [Table G- 6](#).

Table G- 6. Monthly Count of LLDs on South China Sea RNAV Routes

Monitoring Month	Monthly Count of LLDs Reported Over Monitored Fixes	Cumulative 12-Month Count of LLDs Reported Over Monitored Fixes	Monthly Count of LLEs Reported Over Monitored Fixes	Cumulative 12-Month Count of LLEs Reported Over Monitored Fixes
January 2013	0	4	0	0
February 2013	0	4	0	0

Monitoring Month	Monthly Count of LLDs Reported Over Monitored Fixes	Cumulative 12-Month Count of LLDs Reported Over Monitored Fixes	Monthly Count of LLEs Reported Over Monitored Fixes	Cumulative 12-Month Count of LLEs Reported Over Monitored Fixes
March 2013	0	3	0	0
April 2013	0	3	0	0
May 2013	0	3	0	0
June 2013	0	3	0	0
July 2013	0	1	1	1
August 2013	0	1	0	1
September 2013	0	1	2	3
October 2013	0	1	1	4
November 2013	0	1	0	4
December 2013	0	0	0	4

G.3.4 The cause of deviation for the LLD and LLE reports received for the period January 2013 through December 2013 is shown in [Table G- 7](#).

Table G- 7. Cause of LLDs and LLEs on South China Sea RNAV Routes for the period January 2013 through December 2013

Deviation Code	Cause of Deviation	No of Occurrences
E	ATC coordination errors.	4
Total		4

G.4 Risk Assessment and Safety Oversight – compliance with TLS values

G.4.1 The lateral separation standard between the six RNAV routes is 50NM. The form of the lateral collision risk model used in assessing the safety of operations on the South China Sea RNAV routes is:

$$N_{ay} = P_y(S_y)P_z(0) \frac{\lambda_x}{S_x} \left\{ E_y(\text{same}) \left[\frac{|\bar{x}|}{2\lambda_x} + \frac{|\dot{y}(S_y)|}{2\lambda_y} + \frac{|\bar{z}|}{2\lambda_z} \right] + E_y(\text{opp}) \left[\frac{\bar{v}}{\lambda_x} + \frac{|\dot{y}(S_y)|}{2\lambda_y} + \frac{|\bar{z}|}{2\lambda_z} \right] \right\} \quad (1)$$

G.4.2 The longitudinal separation standard for co-altitude aircraft on RNAV routes L642 and M771 is 50-NM. And in December 2013 with the implementation of ADS-B surveillance in the Singapore FIR the longitudinal separation has reduced to 40NM. These two routes are fully covered under surveillance. For the other four RNAV routes, the longitudinal separation standard is either 10 minutes with Mach Number Technique (MNT) or 80NM RNAV.

G.4.3 The form of the longitudinal collision risk model used in assessing the safety of operations on the South China Sea RNAV routes is:

$$N_{ax} = P_y(0)P_z(0) \frac{2\lambda_x}{|\dot{x}|} \left[\frac{|\dot{x}|}{2\lambda_x} + \frac{|\dot{y}(0)|}{2\lambda_y} + \frac{|\dot{z}|}{2\lambda_z} \right] \times \sum_{k=m}^N \sum_{K=k}^M Q(k) \times P(K > k) \quad (2)$$

G.4.4 [Table G- 8](#) and [Table G- 9](#) summarize the value and source material for estimating the values for each of the inherent lateral and longitudinal parameters, respectively, of the internationally accepted Collision Risk Model (CRM).

Table G- 8. Summary of Risk Model Parameters Used in Lateral Safety Assessment

Model Parameter	Definition	Value Used in TLS Compliance Assessment	Source for Value
N_{ay}	Risk of collision between two aircraft with planned 50NM lateral separation	5.0×10^{-9} fatal accidents per flight hour	TLS adopted by APANPIRG for changes in separation minima
S_y	Lateral separation minimum	50NM	Current lateral separation minimum in South China Sea
$P_y(50)$	Probability that two aircraft assigned to parallel routes with 50NM lateral separation will lose all planned lateral separation	2.02×10^{-9}	Value required to meet exactly the APANPIRG-agreed TLS value using equation (1), given other parameter values shown in this table.
λ_x	Aircraft length	0.0399NM	Based on December 2013 TSD operations on L642/M771
λ_y	Aircraft wingspan	0.0350NM	
λ_z	Aircraft height	0.0099NM	
$P_z(0)$	Probability of vertical overlap for airplanes assigned to the same flight level	0.538	Commonly used in safety assessments

Model Parameter	Definition	Value Used in TLS Compliance Assessment	Source for Value
S_x	Length of half the interval, in NM, used to count proximate aircraft at adjacent fix for occupancy estimates	120NM, equivalent to the +/- 15-minute pairing criterion	Arbitrary criterion which does not affect the estimated value of lateral collision risk
$E_y(\text{same})$	Same-direction lateral occupancy	0.0	Result of direction of traffic flows on each pair of RNAV routes
$E_y(\text{opp})$	Opposite-direction lateral occupancy	0.255	Based on December 2013 TSD
\bar{V}	Individual-aircraft along-track speed	507 knots	Based on December 2013 TSD
$ \dot{y}(S_y) $	Average relative lateral speed of aircraft pair at loss of planned lateral separation of S_y	75 knots	Conservative value based on assumption of waypoint insertion error
$ \bar{z} $	Average relative vertical speed of a co altitude aircraft pair assigned to the same route	1.5 knots	Conservative value commonly used in safety assessments

Table G- 9. Summary of Risk Model Parameters Used in Longitudinal Safety Assessment

Model Parameter	Definition	Value Used in TLS Compliance Assessment	Source for Value
N_{ax}	Risk of collision between two co-altitude aircraft with planned longitudinal separation equal to at least the applicable minimum longitudinal separation standard	5.0×10^{-9} fatal accidents per flight hour	TLS adopted by APANPIRG for changes in separation minima
$P_y(0)$	Probability of lateral overlap for airplanes assigned to the same route	0.2	December 2013 TSD
$ \dot{x}(m) $	Minimum relative along-track speed necessary for following aircraft in a pair separated by m at a reporting point to overtake lead aircraft at next reporting point	100 knots	December 2013 TSD
$ \dot{y}(0) $	Relative across-track speed of same-route aircraft pair	1 knot	December 2013 TSD

Model Parameter	Definition	Value Used in TLS Compliance Assessment	Source for Value
m	Longitudinal separation minimum in NM	50NM	Longitudinal separation minimum on L642 and M771
N	Maximum initial longitudinal separation in NM between aircraft pair which will be monitored by air traffic control in order to prevent loss of longitudinal separation standard	150NM	Arbitrary value of actual initial separation beyond which there is negligible chance that actual longitudinal separation will erode completely before next air traffic control check of longitudinal separation based on position reports
M	Maximum longitudinal separation loss in NM observed over all pairs of co-altitude aircraft	Dependent on initial longitudinal separation distance	December 2013 TSD
$Q(k)$	Proportion of aircraft pairs with initial longitudinal separation k	Initial distribution of longitudinal separation for RNAV routes L642 and M771 used in RASMAG/9 safety assessment	December 2013 TSD
$P(K > k)$	Probability that a pair of same-route, co-altitude aircraft with initial longitudinal separation of k NM will lose at least as much as k NM longitudinal separation before correction by air traffic control	Values derived to satisfy TLS of 50NM longitudinal separation minimum	December 2013 TSD

G.5 Safety Assessment

G.5.1 General

G.5.1.1 [Table G- 10](#) summarizes the results of the safety oversight for the airspace, as of December 2013.

Table G- 10. Lateral and Longitudinal Risk Estimation

Type of Risk	Risk Estimation	TLS	Remarks
Lateral Risk	0.055×10^{-9}	5×10^{-9}	Below TLS
Longitudinal Risk	1.18×10^{-9}	5×10^{-9}	Below TLS

G.5.1.2 **Figure G- 1** presents the results of the collision risk estimates for each month using the cumulative 12-month LLD and LLE reports since January 2013.

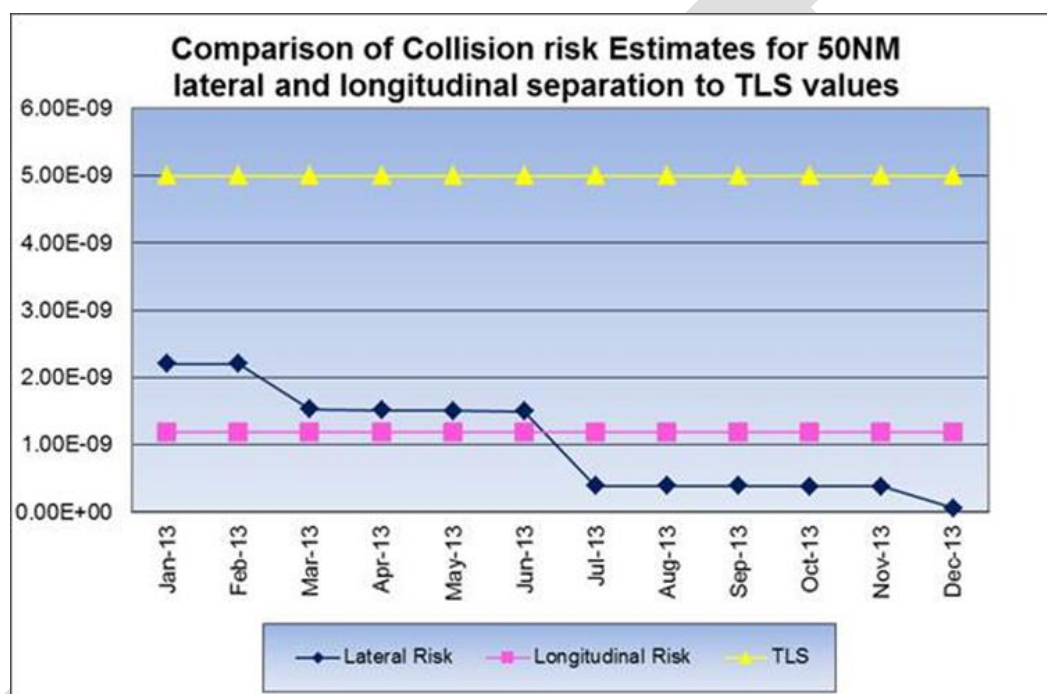


Figure G- 1. Assessment of Compliance with Lateral and Longitudinal TLS Values Based on Navigational Performance Observed During South China Monitoring Program

G.5.1.3 The estimates of lateral and longitudinal risk show compliance with the corresponding respective TLS values during all months of the monitoring period.

G.5.2 Alternate Longitudinal risk assessment using Hsu Model.

G.5.2.1 The Hsu model is used as on trial basis as an ongoing improvement to longitudinal risk assessment. The generalized model states the collision risk [Reference 1] as:

$$CR(t_0, t_1) = 2NP \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{t_0}^{t_1} HOP(t|V_1, V_2) P_z(h_z) \left(\frac{2V_{rel}}{\pi\lambda_{xy}} + \frac{|\bar{z}|}{2\lambda_z} \right) f_1(V_1) f_2(V_2) dt dV_1 dV_2 \quad (3)$$

G.5.2.2 The component HOP(t) represents the probability of the pair of aircraft having a horizontal overlap during a given time interval given the speeds of the pair of aircraft. It is based on reliability theory and is evaluated in terms of multiple integrals of the probability density functions for the along and cross track position errors of each aircraft and is stated in [Reference 1] as:

$$HOP(t|V_1, V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2} e^{-|D_x(t)|/\lambda} \left(\frac{|D_x(t)|}{\lambda} + 1 \right) \quad (4)$$

G.5.2.3 The South China Sea route system comprises of 6 unidirectional non intersecting parallel routes. Thus this risk assessment will only consider the case of same identical track.

G.5.3 Assumptions

G.5.3.1 This assessment takes a conservative approach and does not account for the controller's intervention or system alerts to mitigate collision. [Table G- 11](#) shows the parameters used in the CRM.

Table G- 11. CRM Parameter Values

Parameters	Description	Value	Source
V1	Assumed average ground speed of a/c 1	480knots	Reference 1
V2	Assumed average ground speed of a/c 2	480knots	Reference 1
λ_{xy}	Average aircraft wingspan or length (whichever is greater)	0.0363NM	December 2013 TSD
λ_z	Aircraft height	0.0101NM	December 2013 TSD
λ_v	scale factor for speed error distribution	5.82	Reference 1
T	ADS periodic report	27mins	ICAO Doc 4444
NP	No. of a/c per hour	1	Reference 1
Pz(0)	Probability of vertical overlap for airplanes assigned to the same flight level	0.538	Commonly used in safety assessments

Parameters	Description	Value	Source
$\overline{ z }$	Average relative vertical speed of a co altitude aircraft pair assigned to the same route	1.5knots	Commonly used in safety assessments
τ	controller intervention buffer	3 cases	Reference 1

G.5.3.2 **Table G- 12** shows the summary of the 3 cases of controller's intervention buffer (τ) [reference 1 and 2] used in the computation of the horizontal risk. **Table G- 13**, **Table G- 14** and **Table G- 15** present the detailed component of each of the cases as used in References 1 and 2. The final collision risk is also stated as:

$$0.95 \times (0.95 \times CR(\tau=4) + 0.05 \times CR(\tau=10.5)) + 0.05 \times CR(\tau=13.5)$$

Table G- 12. Cases of τ

τ	Minutes
Case 1: normal ADS ops	4
Case 2: ADS report received & response to CPDLC uplink NOT received in 3 mins	10.5
Case 3: ADS periodic reports takes more than 3 mins	13.5

Table G- 13. Case 1 Normal Operations

Case 1: normal ADS ops	Seconds
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink	90
Pilot reaction	30
Aircraft inertia plus climb	75
Total	240

Table G- 14. Case 2 – ADS Report Received & CPDLC Response Not Received within 3 Minutes

Case 2: ADS report received & response to CPDLC uplink NOT received in 3 mins	Seconds
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink and wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Total	630

Table G- 15. Case 3 – ADS Report Report Not Received

Case 3: ADS periodic reports takes more than 3 mins	Seconds
Controller wait for ADS report	180
Controller message composition	15
CPDLC uplink & wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Extra allowance	30
Total	810

G.5.3.3 In the model, the value for CPDLC uplink is stated as 90 sec [Reference1]. To better model the actual communication, navigation and surveillance (CNS) components, an operational value of CPDLC uplink delivery time could be derived from the actual uplink delivery time database. Further collaboration is needed to collect useful data for analysis. The current ADS-C and CPDLC data collection is shown in [Table G- 16](#).

Table G- 16. ADS CPDLC Uplink Message Delivery Time

Uplink Message Delivery Time	30 s	40 s	60 s	120 s	180 s	360 s	>360 s	Total No. of CPDLC Uplink Messages
Jan-13	87.88%	89.72%	92.91%	98.45%	99.39%	99.91%	100%	19,878
Feb-13	87.21%	89.53%	93.18%	98.30%	99.23%	99.90%	100%	20,594

Uplink Message Delivery Time	30 s	40 s	60 s	120 s	180 s	360 s	>360 s	Total No. of CPDLC Uplink Messages
Mar-13	84.81%	87.50%	91.71%	97.62%	98.92%	99.81%	100%	21,409
Apr-13	85.21%	87.74%	92.06%	97.54%	98.77%	99.71%	100%	23,435
May-13	86.12%	88.45%	92.54%	97.89%	99.09%	99.83%	100%	24,398
Jun-13	86.00%	88.37%	92.59%	97.78%	99.01%	99.85%	100%	23,750
Jul-13	86.08%	88.37%	92.56%	97.94%	99.00%	99.76%	100%	25,632
Aug-13	86.50%	89.06%	93.12%	98.00%	98.99%	99.83%	100%	26,108
Sep-13	86.30%	88.83%	92.87%	98.01%	99.20%	99.84%	100%	25,485
Oct-13	88.01%	89.91%	93.40%	98.10%	99.23%	99.84%	100%	20,552
Average %	86.41%	88.75%	92.69%	97.96%	99.08%	99.83%	100%	23,124

G.5.3.4 **Figure G- 2** presents the comparison of the longitudinal risk estimates using the two methods.

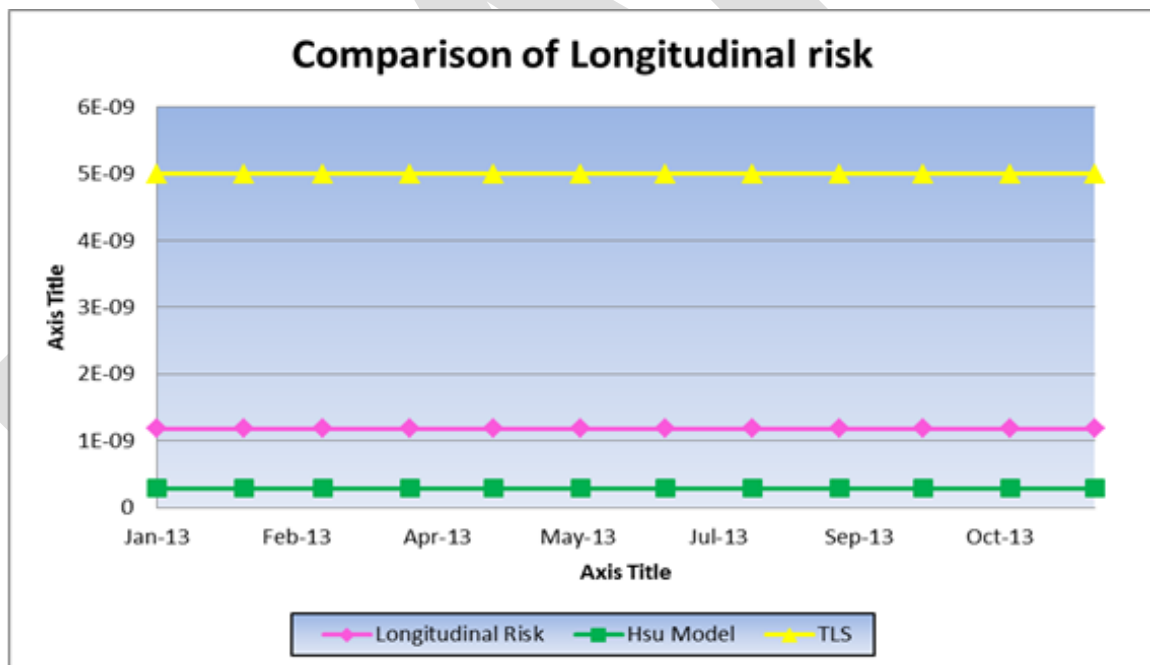


Figure G- 2. Comparison of Longitudinal Risk Values

G.5.3.5 **Table G- 17** compares the longitudinal risk as of December 2013 using the two methods.

Table G- 17. Longitudinal Risk Estimation

Type of Risk	Risk Estimation	TLS	Remarks
Longitudinal Risk	1.18×10^{-9}	5×10^{-9}	Below TLS
Longitudinal Risk Hsu model	0.34×10^{-9}	5×10^{-9}	Below TLS

References

- 1) Anderson, D., “A collision risk model based on reliability theory that allows for unequal RNP navigational accuracy” ICAO SASP-WG/WHL/7-WP/20, Montreal, Canada, May 2005.
- 2) PARMO, “Safety Assessment to support use of the 50-NM Longitudinal, 30-NM Lateral and 30-NM Longitudinal Separation Standards in New York Oceanic Airspace.” Attachment to MAWG/1 WP/2, Honolulu, USA, Dec 2013.

Appendix H EXAMPLE SAFETY ASSESSMENT – HORIZONTAL SEPARATION REDUCTION IN NEW YORK OCEANIC AIRSPACE

H.1 Introduction

H.1.1 The Federal Aviation Administration's (FAA's) Pacific Approvals Registry and Monitoring Organization (PARMO), serves as an En-route Monitoring Agency (EMA) for the Anchorage and Oakland Oceanic Flight Information Regions (FIRs) where the 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation minima have been implemented. These implementations were made possible with the introduction of a new ATC automation system and improvements made in the communication, navigation, and surveillance (CNS) systems by the airspace users and service providers. The reduced horizontal separation minima are available for suitably equipped aircraft pairs.

H.1.2 The purpose of this appendix is to present an example of a safety assessment, as conducted by PARMO for New York oceanic airspace, together with the collision risk models used, to assess compliance with the ICAO Target Level of Safety (TLS) values for the maintenance of lateral and longitudinal separation standards.

H.2 Background

H.2.1 In combination with data collected from the area of application, the ICAO-endorsed collision risk methodology is used to prepare an estimate of the collision risk upon introduction of the 50-NM longitudinal, 30-NM lateral, and longitudinal separation minima. These risk estimates will be compared to the TLS of 5×10^{-9} fatal accidents per flight hour (fapfh) due, separately, to the loss of 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation, following the guidelines for implementing these separation minima in international airspace contained in ICAO Documents 9689 and 9869.

H.2.2 In New York oceanic airspace, the controller decision support system is the FAA's automated oceanic air traffic control (ATC) system, Ocean21. The decision support system is used to project a conflict-free path for an aircraft between it and others with applicable separation minima. The Ocean21 system is fully compliant with the requirements contained within ICAO Doc 4444 regarding the application of ADS-C and controller-pilot data link communications (CPDLC) in support of 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation standards, such as:

- a) Establishing ADS-C contracts with an appropriate periodic update rate for suitably approved aircraft;
- b) Establishing a lateral deviation event contract set to 5-NM; and
- c) Reversion to an alternate procedural separation if ADS-C message is overdue by 3 minutes and 6 minutes have elapsed since controller began attempting to establish communication.

H.2.3 The operator and aircraft requirements for the use of the 50-NM longitudinal separation standard include approval for Required Navigation Performance (RNP)-10 along with direct controller-pilot communications (DCPC). The operator and aircraft requirements for the use of 30-NM lateral and 30-NM longitudinal separation standards include approval for RNP 4 along with DCPC. The use of satellite data link communications involving CPDLC is considered to be DCPC as stated in ICAO Doc 4444, paragraph 5.4.2.6.2.2. In addition, the application of the reduced separation will require the communication systems to meet the Required Communication Performance (RCP) type 240 and Required Surveillance Performance (RSP) type 180 specifications contained in ICAO Doc 9869.

H.2.4 As part of the safety assessment, this appendix provides verification that the ADS-C requirements contained in ICAO Doc 4444, as they pertain to the application of the 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation minima, are satisfied in New York oceanic airspace. In addition, this document provides comparisons of important parameter values in the airspace of application to those of ICAO Doc 9689 used in development of the requirements for safe application of the reduced horizontal separation minima under the general assumptions of RNP and the use of CPDLC and ADS.

H.3 Description of New York Oceanic Airspace

H.3.1 **Figure H- 1** shows the location of New York oceanic airspace. The western portion of New York oceanic airspace contains a fixed airway route structure referred to as the Western Atlantic Route System (WATRS). The WATRS airspace primarily contains operations travelling between North America and the Caribbean. The eastern portion of New York oceanic airspace will be referred to as a portion of the North Atlantic (NAT) airspace in this document. The NAT airspace primarily contains operations travelling between North America and Europe. The U.S. FAA is the ATS provider for the New York Oceanic FIR. The northern oceanic boundary of New York oceanic airspace borders the Gander FIR which is controlled by Transport Canada/NavCanada. The eastern boundary of the New York FIR borders the Santa Maria FIR which is controlled by Navagacao Aerea de Portugal.

H.3.2 An extensive analysis of operations conducted within New York oceanic airspace is contained in the Know Your Airspace (KYA) conducted by the FAA Technical Center and presented to the Fifteenth Meeting of the North Atlantic Safety Analysis and Reduced Separation Implementation Group (SARSIG/15) in March 2012. The KYA study contains summarized details of observed airspace operations, data link communication performance, aircraft type population, ADS-C usage, operator RNP filing, and CPDLC element usage from data collected during the time period of September 2010 through August 2011. An estimated average of 544 flights per day operates within New York oceanic airspace. There is significant seasonal variability associated with the traffic volume in the various portions and directions of travel within the New York FIR. High traffic volumes were observed in the WATRS portion of the New York FIR during the months of December, January, March and April. Whereas, higher traffic volumes were observed in the NAT portion of the New York FIR during the months of June, July, and August.

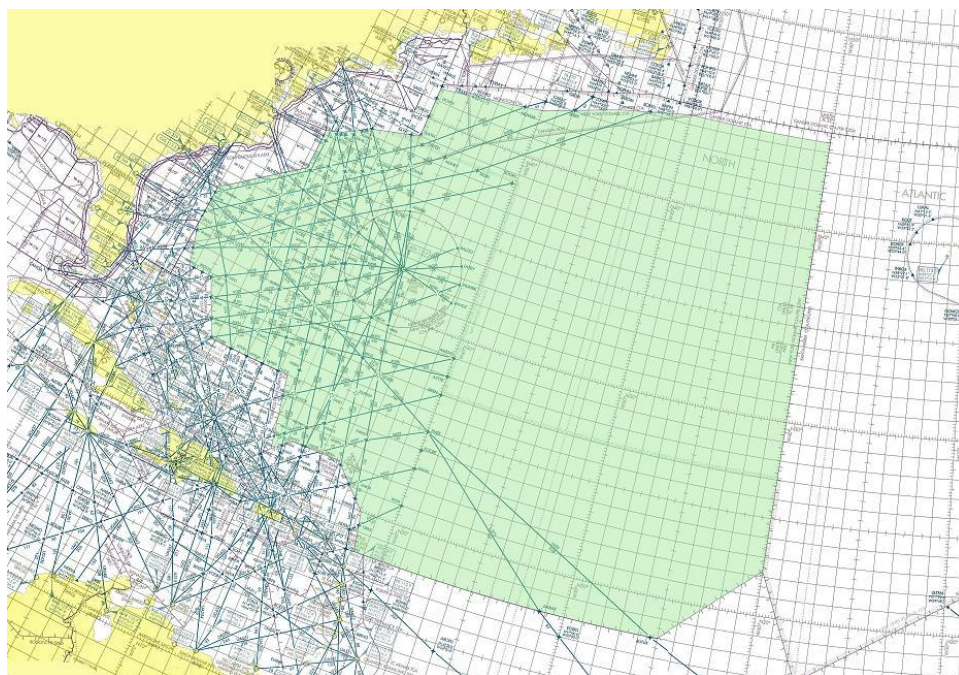


Figure H-1. New York Oceanic Airspace

H.4 Operators and Aircraft Types Eligible for the Reduced Horizontal Separation Minima

H.4.1 An operator and aircraft must have State approval for RNP 4 operations, and be equipped with CPDLC and ADS-C in order to be eligible for application of the 30-NM lateral and 30-NM longitudinal separation minima. The 50-NM longitudinal separation minimum requires that an operator and aircraft have State approval for RNP 10 operations and be equipped with CPDLC and ADS-C. All U.S. registered aircraft require a separate approval for data link operations.

H.4.2 In addition, the application of the reduced longitudinal separation will require the performance of the communication systems to meet the RCP type 240 and RSP type 180 specifications as contained in ICAO Doc 9869.

H.4.3 [Table H- 1](#) provides the observed proportions of operations eligible for the 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation minima. Operations using ADS-C for position reporting and indicating RNP 4 in the filed flight plan are eligible for the 30-NM lateral and 30-NM longitudinal separation minima. Operations using ADS-C for position reporting and indicating RNP 10 or RNP 4 in the filed flight plan are eligible for the 50-NM longitudinal separation minimum. It is noted that the RNP 4 operations not using ADS-C in [Table H- 1](#) are typically State aircraft RNP 4 operations without data link.

H.4.4 It is noted that some operations occur in both the WATRS and NAT portions of the airspace, these operations are counted in both the NAT and WATRS total number of operations. Because of this, the total number of observed operations indicated in the lower right corner of [Table H- 1](#) (52,718), is not equal to the sum of the number of operations observed in the NAT (24,421) and WATRS (44,270).

Table H- 1. Proportions of Operations Indicating RNP 4/RNP 10 in the Filed Flight Plan and Utilizing ADS-C in New York Oceanic Airspace; March - May 2012

	NAT		WATRS		ZNY	
	ADS-C	Non ADS-C	ADS-C	Non ADS-C	ADS-C	Non ADS-C
RNP 4	5.90%	2.98%	4.17%	2.39%	3.90%	2.32%
RNP 10	50.47%	38.06%	22.91%	68.59%	27.05%	64.60%
Non RNP 10	0.00%	0.02%	0.00%	0.07%	0.00%	0.07%
Total Number of Operations	24,421		44,270		52,718	

H.4.5 **Table H- 1** shows that a majority of the operations in New York oceanic airspace are eligible for the 50-NM longitudinal separation minimum. In the NAT and WATRS portions of the airspace, roughly 50 and 23 percent, respectively, of the traffic use ADS-C and file RNP 10 or better. Fewer operations are eligible for the application of the 30-NM lateral and 30-NM longitudinal separation minima, roughly 6 and 4 percent of operations within the NAT and WATRS portions, respectively, meet the requirements for the application of the 30-NM horizontal standards.

H.4.6 **Table H- 2** displays the proportions of aircraft types, in terms of numbers of operations, observed using ADS-C for position reporting and indicating RNP 4 or RNP 10 in the filed flight plan in New York oceanic airspace. These data were collected during the months of March through May 2012. It can be assumed that operations which indicate RNP 4 approval also satisfy the performance requirements for RNP 10, therefore the RNP 10 data on the right side of **Table H- 2** also includes operations that indicated RNP 4 approval.

H.4.7 The top 2 aircraft types, A332 and B777-200, represent approximately 2% of the operations eligible for the 30-NM lateral and longitudinal separation minima. These same aircraft types, A332 and B772, represent more than 11 percent of the operations eligible for the 50-NM longitudinal separation minimum.

H.4.8 The top 5 aircraft types indicating RNP 10 and using ADS-C represent roughly 21 percent of all operations which are eligible for the 50-NM longitudinal separation minimum. The top 5 aircraft types indicating RNP 4 and using ADS-C represent approximately 3 percent of all operations which are eligible for the 50-NM longitudinal separation minimum.

Table H- 2. Aircraft Types Indicating RNP 4/RNP 10 in the Filed Flight Plan and Utilizing ADS-C in New York Oceanic Airspace

RNP 4			RNP 10		
Aircraft Type	Proportion of All Operations	Cumulative Proportion	Aircraft Type	Proportion of All Operations	Cumulative Proportion
A332	1.17%	1.17%	B772	5.89%	5.89%
B772	0.80%	1.97%	A332	5.70%	11.60%
A333	0.75%	2.72%	B744	3.68%	15.27%

RNP 4			RNP 10		
Aircraft Type	Proportion of All Operations	Cumulative Proportion	Aircraft Type	Proportion of All Operations	Cumulative Proportion
B764	0.31%	3.02%	A333	3.09%	18.36%
C17	0.17%	3.20%	A346	3.00%	21.36%
C5/H	0.15%	3.35%	A343	2.64%	24.00%
MD11	0.10%	3.45%	B77W	1.89%	25.89%
A345	0.09%	3.54%	B763	1.26%	27.16%
K35R	0.08%	3.62%	B764	1.23%	28.39%
A343	0.05%	3.67%	B77L	0.47%	28.86%
GLF5	0.05%	3.72%	C17	0.38%	29.24%
B744	0.05%	3.77%	B752	0.26%	29.50%
A388	0.04%	3.80%	GLF5	0.23%	29.73%
B762	0.03%	3.83%	MD11	0.21%	29.94%
B77W	0.02%	3.85%	C5/H	0.20%	30.14%

H.5 Safety Assessment Methodology

H.5.1 General

H.5.1.1 In accordance with the requirements and guidance of ICAO Documents 4444, 9689 and 9869, the safety assessment provides estimates of the risk of collision which will pertain when 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation minima are applied in New York oceanic airspace and compares this risk to the specified Target Level of Safety (TLS).

H.5.1.2 As stated in ICAO Doc 9689, Paragraph 3.2.1, the value of the TLS which applies to both the lateral and longitudinal dimensions is 5×10^{-9} fatal accidents per flight hour (fapfh). This is also in accordance with NAT SPG conclusions pertaining to reductions in lateral and longitudinal separations for the NAT region.

H.5.1.3 Estimation of collision risk in this safety assessment is carried out using the general collision risk model, as described in ICAO Doc 9689, which has different forms for the lateral and longitudinal dimensions. No explicit derivations of these two model forms are provided in this safety assessment. The interested reader is referred to the portions of ICAO Doc 9689 for the technical details of the assumptions and mathematical details of the models.

H.5.2 Lateral Collision Risk Model

H.5.2.1 The form of the lateral collision risk model applicable to assessing the risk, N_{ay} , of a 30-NM lateral separation standard from Appendix 15 of ICAO Doc 9689 is:

$$N_{ay} = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}\left\{E_y(\text{same})\left[\frac{|\dot{x}|}{2\lambda_x} + \frac{|\dot{y}(S_y)|}{2\lambda_y} + \frac{|\dot{z}|}{2\lambda_z}\right] + E_y(\text{opp})\left[\frac{|\dot{V}|}{\lambda_x} + \frac{|\dot{y}(S_y)|}{2\lambda_y} + \frac{|\dot{z}|}{2\lambda_z}\right]\right\} \quad (1)$$

where the individual parameters of the lateral collision risk model and their definitions are given in [Table H- 3](#).

Table H- 3. Lateral Collision Risk Model Parameters

Term	Definition
S_x	Nominal distance defining proximity of aircraft on adjacent parallel track to a typical aircraft
S_y	Lateral separation minimum
$P_z(0)$	Probability of vertical overlap (with planned vertical separation equal to zero)
$P_y(S_y)$	Probability of lateral overlap (with planned lateral separation equal to S_y)
λ_x	Average aircraft length
λ_y	Average aircraft wingspan (or width)
λ_z	Average aircraft height with undercarriage retracted
$E_y(\text{same})$	Same-direction lateral occupancy for a pair of aircraft on adjacent routes separated by distance S_y on the same flight level
$E_y(\text{opp})$	Opposite-direction lateral occupancy for a pair of aircraft on adjacent routes separated by distance S_y on the same flight level.
$N_x(\text{same})$	Same direction passing longitudinal frequency
$N_x(\text{opp})$	Opposite direction longitudinal passing frequency
\bar{V}	Average aircraft ground speed
$ \dot{x} $	Average absolute relative along-track speed between aircraft pairs
$ \dot{y}(S_y) $	Average absolute relative cross-track speed between aircraft pairs operating on tracks nominally separated by S_y
$ \dot{z} $	Average absolute relative vertical speed between aircraft pairs

H.5.3 Longitudinal Risk Model

H.5.3.1 The generalized form of the longitudinal collision risk model applicable to assessing the risk, the number of accidents per flight hour, N_{ax} , associated with the 50-NM and 30-NM longitudinal

separation minima is given in Appendix 1 of ICAO Doc 9689. Assuming that the aircraft pair are on the same identical ground track, the collision risk during a time interval $[t_0, t_1]$ is given by

$$CR(t_0, t_1) = 2NP \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} \int_{t_0}^{t_1} HOP(t | V_1, V_2) P_z(h_z) \left(\frac{2V_{rel}}{\pi\lambda_{xy}} + \frac{|\vec{z}|}{2\lambda_z} \right) f_1(V_1) f_2(V_2) dt dV_1 dV_2 \quad (2)$$

H.5.3.2 In equation (2) the speeds, V_1 and V_2 , of the two aircraft are assumed to follow the same double exponential distribution with known means and the same scale parameter, λ_v . The integral over V_1 and V_2 with their respective probability distributions $f_1(V_1)$ and $f_2(V_2)$ accounts for the variation in aircraft speed around the nominal speed.

H.5.3.3 The term for the horizontal overlap probability (HOP) considers the along-track and cross-track position errors of two longitudinally separated aircraft. An equation for HOP for operations on the same ground track (e.g. angle of zero degrees) is given in Appendix 1 of ICAO Doc 9689 as:

$$HOP(t | V_1, V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2} e^{-|D_x(t)|/\lambda} \left(\frac{|D_x(t)|}{\lambda} + 1 \right) \quad (3)$$

H.5.3.4 In equation (3) $D_x(t)$ is the distance between the aircraft pair and λ is the scale parameter for the along-track and cross-track position error distributions. Along-track and cross-track deviations are modeled with a double exponential distribution. The maximum acceptable scale parameter, λ , for a specified RNP value or a navigation accuracy value of k is $\frac{k}{-\ln(0.05)}$.

H.5.3.5 The application of the 30-NM longitudinal separation minimum requires aircraft to navigate to the 4-NM/95 percent accuracy criteria of RNP 4. It is known that aircraft with State Approval for RNP 4 navigate using Global Navigation Satellite Systems (GNSS). Actual aircraft performance for aircraft utilizing GNSS for navigation is much better than RNP 4. To model the more accurate performance of GNSS navigation correctly, the value of k for GNSS aircraft is 0.3-NM. Risk estimate comparisons will be made between RNP 4 and the assumed observed navigation performance for GNSS aircraft ($k = 0.3$ -NM).

H.5.3.6 The application of the 50-NM longitudinal separation minimum requires aircraft to navigate to the 10-NM/95 percent accuracy criteria of RNP 10. However, the actual navigation performance may be better than RNP 10 as aircraft eligible for the 30-NM longitudinal separation with RNP 4 are also eligible for the 50-NM longitudinal separation.

H.5.3.7 The time integral is evaluated over $t \in [0, T + \tau]$ where T is the ADS reporting period and τ is the controller intervention buffer. Appendix 1 of ICAO Doc 9689 considers three cases under an ADS environment and provides the components for τ for each case. The components for each of the three cases are replicated here for clarity.

- a) Under normal ADS operation, an allowance of 4 minutes is assumed for the value of τ (Table H-4).

- b) In the case where the periodic ADS reports are received and a response to the CPDLC uplink is not received in 3 minutes, an allowance of 10 ½ minutes is assumed for the value of τ (Table H-5). These limits are the primary source for the time requirements in ICAO Doc 4444 for ATC to revert to a larger separation (ICAO Doc 4444, paragraph 5.4.2.6.4.3.2).
- c) When the ADS periodic report is lost or takes longer than 3 minutes (Table H-6).

H.5.3.8 All of the components for τ used in the collision risk estimation for New York oceanic airspace conform to those provided in Table H-4 through Table H-6 except for the CPDLC uplink time. Appendix 1 in ICAO Doc 9689 assumes a static value of 90 seconds to the CPDLC uplink transit time. This appendix uses an empirical distribution for the CPDLC uplink transit time based on observed performance in New York oceanic airspace. This distribution is explained in subsequent sections of this appendix.

Table H- 4. Components of τ for normal ADS operations

Component	Value (seconds)
Screen update time/controller conflict Recognition	30
Controller message composition	15
CPDLC uplink	90
Pilot reaction	30
Aircraft inertia plus climb	75
Total	240

Table H- 5. Components of τ when response to CPDLC uplink is not received requiring HF communication

Component	Value (seconds)
Screen update time/controller conflict recognition	30
Controller message composition	15
CPDLC uplink and wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Total	630

Table H- 6. Components of τ when ADS-C periodic report takes longer than 3 minutes

Component	Value (seconds)
Controller wait for ADS report	180

Component	Value (seconds)
Controller message composition	15
CPDLC uplink and wait for response	180
HF communication	300
Pilot reaction	30
Aircraft inertia plus climb	75
Extra allowance	30
Total	810

H.5.3.9 The additional parameters needed for the longitudinal collision risk model and their definitions are given in [Table H- 7](#).

Table H- 7. Additional Parameters Needed for the Longitudinal CRM

Term	Definition
V_1	Assumed speed (knots) of aircraft 1
V_2	Assumed speed (knots) of aircraft 2
λ_{xy}	Equal to either the average aircraft wingspan or length, whichever is larger
V_{rel}	$\sqrt{V_1^2 + V_2^2 - 2V_1V_2 \cos \theta}$ = relative horizontal speed between aircraft 1 and aircraft 2
NP	Number of aircraft pairs per flight hour
$[t_o, t_l]$	Time interval over which two aircraft are considered to be longitudinally separated
$D_x(t)$	Distance between the two aircraft over the time interval $[t_o, t_l]$
λ_v	Scale parameter for the speed error (about the nominal speed) distribution
T	ADS periodic report interval
τ	Controller intervention buffer which is the time for the controller to intervene, convey instructions to the pilot and for the pilot to react and cause the aircraft to achieve a change of trajectory sufficient to ensure that a collision will be averted

H.5.3.10 Interpretation of the parameters in [Table H- 3](#) and [Table H- 7](#) are given later in this appendix, several of which have values that are readily obtained.

H.6 Data Sources Used for the Safety Assessment

H.6.1 General

H.6.1.1 Several data sources are used to assist in conducting this safety assessment. These data sources provide insight into the operations of New York oceanic airspace, and support the estimation of values for several of the parameters shown in [Table H- 3](#) and [Table H- 7](#).

H.6.2 Safety Databases

H.6.2.1 Relevant extracts from safety databases that contain information regarding all reported instances of operational errors made by flight crews or air traffic controllers were made available for this safety assessment.

H.6.2.2 Many reports that are of value to this study are also reported to the North Atlantic Central Monitoring Agency (NAT CMA), particularly if the events occur in the MNPS portion of this airspace. A cross check of events available in the safety databases and the NAT CMA database indicates that each database contains the same reports for New York MNPS airspace during the calendar interval covered by this study.

H.6.3 Ocean21 Archived Data

H.6.3.1 The supporting data for this safety assessment covers the one-year time period of June 2011 through May 2012. These data consist of all the flight plans, and the HF, CPDLC, and ADS-C communication messages provided from the comprehensive data reduction and analysis (DR&A) capabilities of the Ocean21 system.

H.7 Examination of Proximate Aircraft Operations in New York Oceanic Airspace

H.7.1 The Ocean21 system became fully operational at New York Oceanic Center in June 2006 after undergoing extensive preparation. New York automation specialists have provided the Technical Center with all data archived from the system for the period 1 June 2011 through 31 May 2012 for use in conducting the safety assessment.

H.7.2 The packing of aircraft in New York oceanic airspace is important to risk estimation. Definitive information on aircraft packing is gained from the history of inter-aircraft separations operating within the airspace. The separation of aircraft pairs are examined upon entry into the airspace as well as during the operation within the airspace.

H.7.3 To examine the aircraft-packing in New York oceanic airspace, separations between aircraft pairs are observed. Pilot/aircraft reported position times, available in the archived Ocean21 data are analyzed for aircraft pairs operating within the airspace. These data were examined for the twelve-month period of June 2011 through May 2012. The Ocean21 data used for this analysis contained aircraft positions derived from ADS-C, CPDLC, and HF position reports. However, only the data from aircraft pairs in which both aircraft are utilizing ADS-C are maintained in the analyses.

H.7.4 Two aircraft are considered to be a longitudinal proximate pair if both aircraft are using ADS-C, are operating at the same flight level, and are reporting over a common position within 15 minutes of each other. The longitudinal separation between proximate ADS-C aircraft within New York oceanic airspace is observed in terms of distance and time.

H.7.5 There were 749 aircraft pairs identified during the twelve month sample period. These pairs were observed to have reported over a common position at the same altitude within 15 minutes of each other. The time intervals are organized into bins of 1 minute and presented in [Figure H- 2](#). The minimum longitudinal separation in terms of time was observed to be 5.767 minutes and the maximum longitudinal separation observed was 15 minutes. The mean value for the longitudinal separation observed was 12.268 minutes.

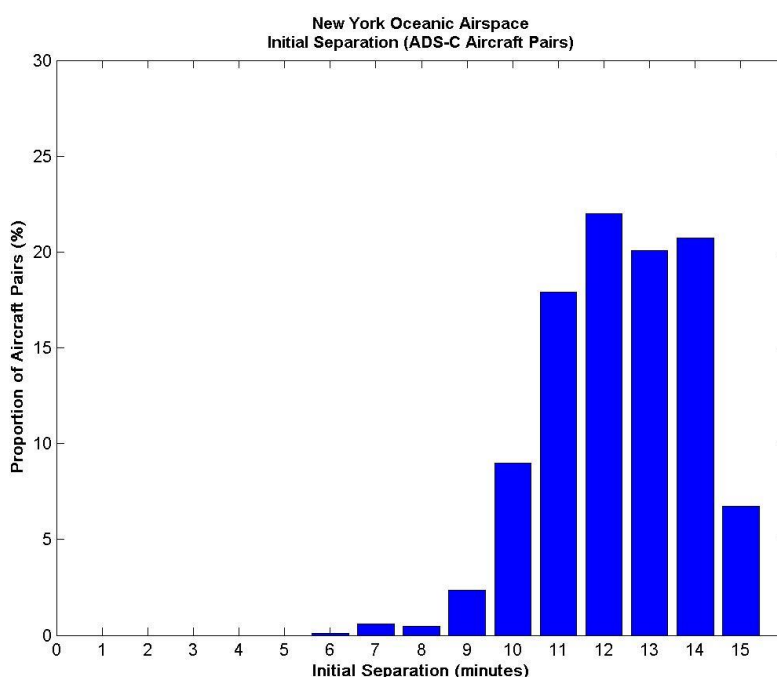


Figure H- 2. Initial Separation (Time) between Longitudinally Proximate ADS-C Operations within New York Oceanic Airspace – June 2001 through May 2012

H.7.6 The data in [Figure H- 2](#) show a small number of aircraft pairs observed with initial separations less than 10-minutes consisted of a faster aircraft in front of an aircraft operating at a slower speed, the observed separation increased for all of these aircraft pairs.

H.7.7 The same data presented in [Figure H- 3](#) are observed in terms of distance. The distance intervals are organized into bins of 5-NM and are presented in [Figure H- 3](#). The distances between aircraft pairs are calculated by interpolating between the ADS-C reports to determine the location and time of aircraft at common points. The resulting distances are computed as great circle distances between the airplanes at the moment the trailing aircraft crossed the common point. The minimum longitudinal separation in terms of distance was observed to be 46.133-NM and the maximum longitudinal separation observed in the data sample was 146.061-NM. The mean value for the longitudinal separation observed was 99.224-NM.

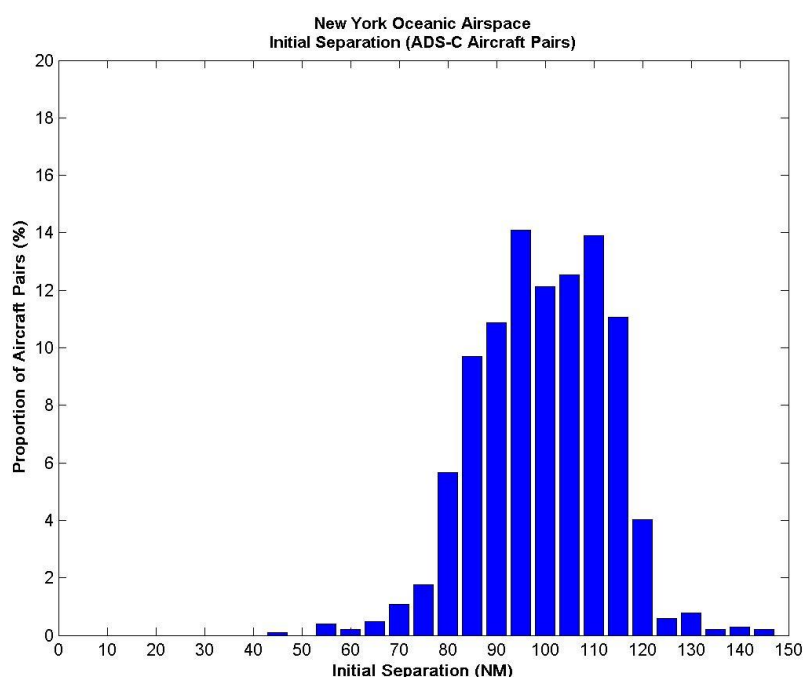


Figure H- 3. Initial Separation (Distance) between Longitudinally Proximate ADS-C Operations within New York Oceanic Airspace – June 2001 through May 2012

H.7.8 The data in [Figure H- 3](#) show evidence of the application of the current 10-minute longitudinal separation minimum in New York oceanic airspace. Using an average ground speed of 480 knots, the application of the 10-minute longitudinal separation minimum is observed beginning with 80-NM in [Figure H- 3](#). The same observation noted from the data presented in [Figure H- 2](#) is also observed in [Figure H- 3](#). There are a small number of aircraft pairs with initial separation less than 80-NM. All of these aircraft pairs consisted of an aircraft operating at a faster speed than the following aircraft, the observed separation increased for all of these aircraft pairs.

H.7.9 Most of the 749 ADS-C aircraft pairs observed in the data sample were travelling in the east/west direction in the New York oceanic airspace. There were 403 and 335 aircraft pairs observed to be traveling in the east and west direction, respectively. There were 9 and 2 aircraft pairs observed to be traveling in the north and south direction, respectively. This result is due to the imposed data sampling requirement that both aircraft use ADS-C for position reporting. The north/south traffic flows primarily consist of operations conducted on the WATRS routes, fewer WATRS operations currently utilize ADS-C and data link for ATC communication relative to NAT operations within New York oceanic airspace.

H.7.10 Of the 749 aircraft pairs identified during the time period June 2011 through May 2012, 69 aircraft pairs, or approximately 9 percent of the observed aircraft pairs, would have been eligible for either the 30-NM or 50-NM longitudinal separation. Operations filing RNP 4 in the flight plan and using ADS-C/CPDLC for position reporting and communication with air traffic control are eligible for the 30-NM longitudinal separation standard.

H.7.11 The remaining 680 aircraft pairs, or approximately 91 percent of the observed pairs during the 12-month sample period, would have been eligible for the 50-NM longitudinal separation standard

only. Both aircraft in the pair must be approved for RNP10 operations, file RNP 10 in the flight plan, and utilize ADS-C/CPDLC for position reporting and communication.

H.8 Analysis of Data Retrieved from Safety Databases

H.8.1 The FAA safety databases, reports filed under FAA Order 7110.82D and contemporaneous NAT CMA archives were examined for the period June 2011 through December 2012 in a search for events of possible importance to the application of the reduced horizontal separation minima.

H.8.2 The data sources produced 19 reports, relating to longitudinal and lateral events. A summary of each of these 19 events is provided in [Table H- 8](#). The corresponding code definitions for horizontal-plane error reports are presented in [Table H- 9](#).

Table H- 8. Summary of Reports Reviewed in Connection with Safety Assessment

Event Date	Event Type	Magnitude	Codes
6/3/2011	Lateral	15-NM	W
8/4/2011	Lateral	10-NM	W
8/27/2011	Lateral	15-NM	W
9/8/2011	Lateral	54-NM	C4,W
9/17/2011	Lateral	8-NM	W
10/20/2011	Lateral	50-NM	C4
10/24/2011	Lateral	10-NM	C4,W
11/10/2011	Lateral	25-NM	C4,W
11/13/2011	Lateral	40-NM	C4,W
4/2/2012	Lateral	50-NM	C3
8/29/2012	Lateral	50-NM	G
9/3/2012	Lateral	50-NM	C3
10/8/2012	Lateral	50-NM	C4, W
10/27/2012	Lateral	20-NM	C4, W
11/5/2012	Lateral	50-NM	C3
11/6/2012	Lateral	70-NM	C4
11/15/2012	Lateral	10-NM	C4
11/18/2012	Lateral	20-NM	C4, W
12/27/2012	Lateral	25-NM	C3

Table H- 9. Description of horizontal event codes

Error Class	Description	Examples
A	Committed by aircraft not authorized for RNP 10 or RNP 4 operations	
B	ATC loop error, broken down into four categories as follows:	
B1	Controller error	
B2	Poor information exchange between controller and the third party communicator	
B3	Poor information exchange between pilot and the third party communicator	
B4	Poor center to center coordination	
C1	Equipment control error encompassing incorrect operation of fully functional FMS or navigation system	By mistake the pilot incorrectly operates INS or other navigation equipment
C2	Incorrect transcription of ATC clearance or re-clearance into the FMS	
C3	Wrong information faithfully transcribed into the FMS, e.g., flight plan followed rather than ATC clearance or original clearance followed instead of re-clearance	
C4	Pilot fails to follow ATC clearance	
D	Other with failure to notify ATC in time for action	Errors in classes D, E, and F are primarily due to equipment failure
E	Other with failure to notify ATC too late for action	
F	Other with failure not notified/received by ATC	
G	Inter-facility co-ordination problem	
W	Weather Event – If primary code weather; deviation executed properly. If secondary code; weather was a contributing factor-deviation not executed properly	

H.8.3 The events used in the lateral risk assessment are those with a lateral magnitude greater than or equal to 15-NM. For the collection period from June 2011 through December 2012, there were 15 lateral events with a deviation magnitude greater than or equal to 15-NM. Reports of these types will continue to be monitored by the FAA Technical Center.

H.9 Aircraft Lateral Deviations

H.9.1 The Ocean21 system automatically establishes a 5-NM lateral deviation event contract with all ADS-C aircraft operating in New York oceanic airspace. This event contract notifies the Ocean21 system and the air traffic controller, via a lateral deviation contract (LDC) report, of an aircraft

lateral deviation once the deviation magnitude exceeds 5-NM from intended course. New York ARTCC uses the LDC event contract and report to confirm the direction of a cleared deviation from track.

H.9.2 **Figure H- 4** displays the proportions of LDC reports in terms of reports per month. These data were collected during the period June 2011 to May 2012. Roughly 17 percent of the LDC reports occurred during August 2011. An average of approximately 712 LDC reports is received each month.

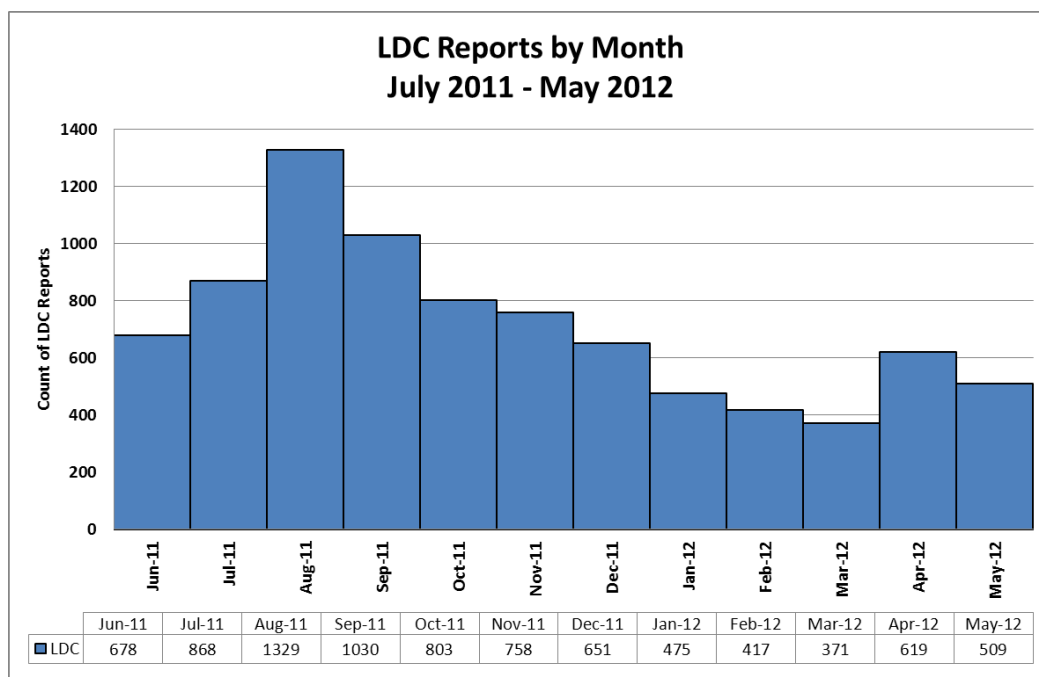


Figure H- 4. Count of LDC Reports per month – June 2011 to May 2012

H.9.3 **Figure H- 5** provides the locations of the LDC reports for the month of August 2011. The red markers indicate the location of the aircraft at the time the LDC report was sent. The boundary of New York Oceanic airspace is also shown in the figure.

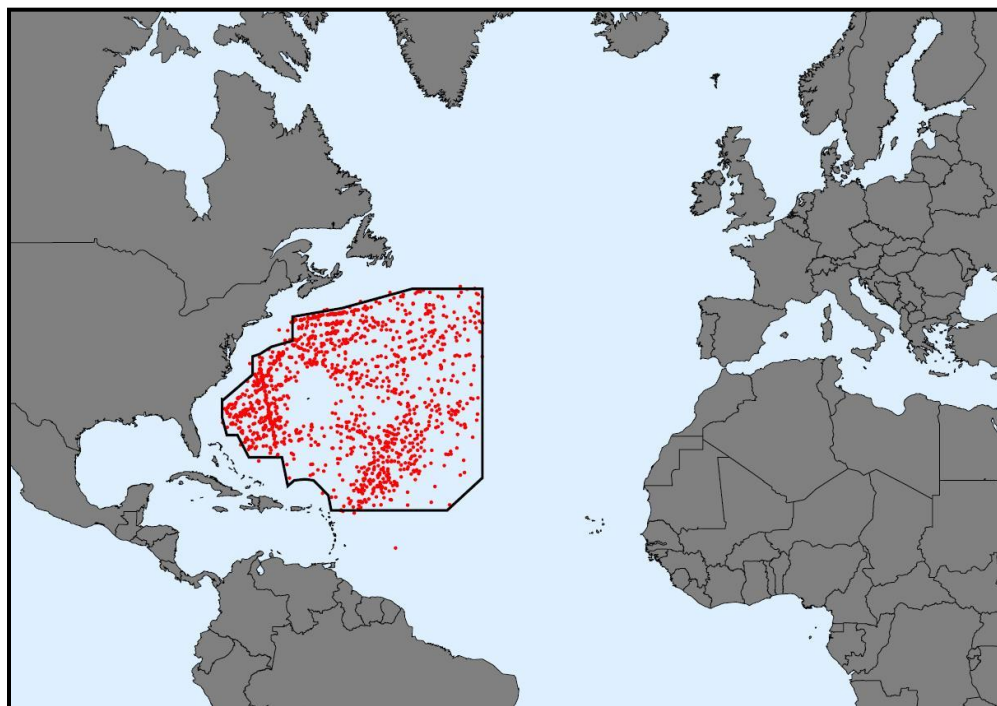


Figure H- 5. Locations of Received LDC Event Reports for August 2011

H.10 Weather Deviations

H.10.1 Pilots are expected to follow the prescribed weather deviation procedures when weather systems are encountered within New York oceanic airspace. These procedures must be invoked if the weather system necessitates a lateral deviation from their cleared route of flight. A pilot request for a deviation due to weather is sent to the controller via HF or CPDLC, and these requests are recorded in the archived Ocean21 data.

H.10.2 The CPDLC and HF messages containing pilot requests for weather deviations in New York oceanic airspace were examined for the period of June 2011 through May 2012. Weather deviation requests via CPDLC are typically made using downlink message element “DM 27.” All CPDLC downlink messages with message element “DM 27” were extracted from the archived CPDLC data. Weather deviation requests via HF are not as straightforward to identify. Frequently occurring key words used by the aircraft operators to make weather-related deviation requests via HF were first observed. These words were then used to extract the HF requests for deviation due to weather from the one-year sample of archived HF data.

H.10.3 During the one-year sample period, there were 22,149 flight operations identified as having at least one pilot request for a weather deviation, equating to approximately 11 percent of the total flight operations observed during the period. There were a total of 28,972 requests, approximately 48 percent of which were made via CPDLC and 52 percent were made via HF. [Figure H- 6](#) shows the count of weather deviation requests observed by month during the one-year sample period, with the proportion of CPDLC and HF highlighted in each.

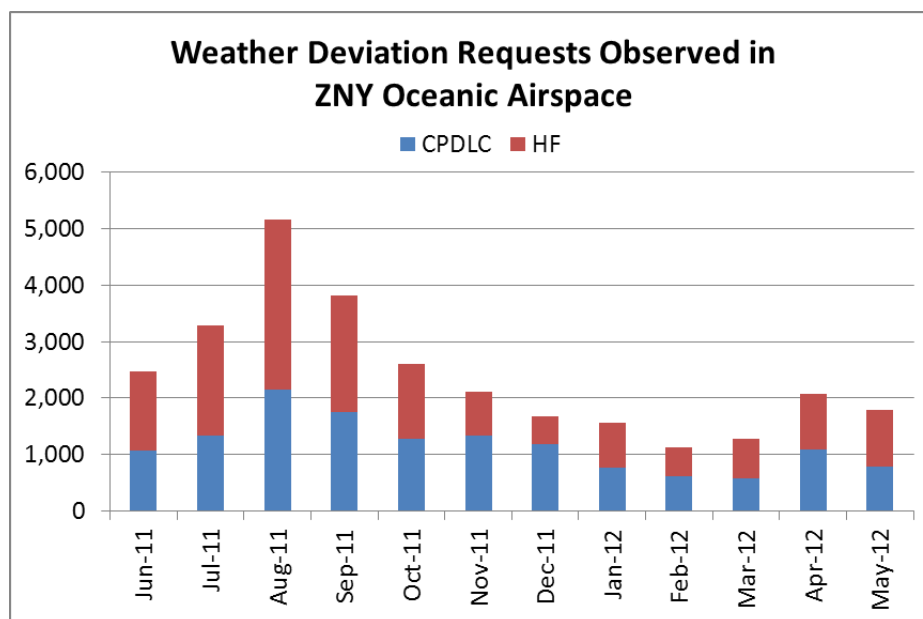


Figure H- 6. Weather deviation requests observed in New York Oceanic Airspace by month

H.10.4 **Figure H- 7** illustrates the relative frequency distribution of the magnitudes of the weather deviation requests observed during the period from June 2011 to May 2012. Approximately 93 percent were 50-NM or less and 70 percent were 30-NM or less.

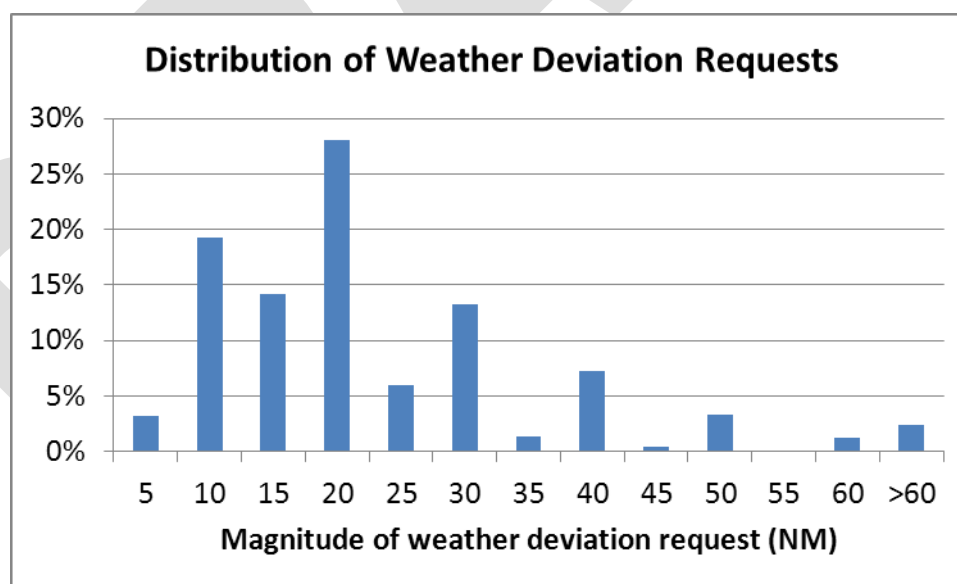


Figure H- 7. Distribution of weather deviation requests – magnitudes (NM)

H.10.5 The corresponding controller responses to these requests were also examined. The uplink clearances issued via both HF and CPDLC are generally sent in a fixed format message allowing a

straightforward extraction from the archived data. CPDLC clearances are made using uplink message element number “UM 82.” The responses were matched to the respective weather deviation requests by comparing associated aircraft IDs and message times.

H.10.6 **Table H- 10** summarizes the observed weather deviation requests and corresponding responses for the sample of weather deviation requests covering June 2011 to May 2012. There were 472 flights observed making weather deviation requests via both CPDLC and HF, approximately two percent of the total flights observed making weather deviation requests.

H.10.7 In the case of an “Unable” response, it was observed that ATC typically gives an alternative option, such as a deviation in the opposite direction, a level change, or a re-route.

H.10.8 The remaining eight percent of total requests not observed with a clearance or unable response includes cases where an additional request was sent by the pilot before a response to the first request was received, where the CPDLC connection was closed prior to a response being received, or where none of the expected responses was identified in the data.

Table H- 10. Summary of weather deviation requests and responses

	CPDLC	HF	Total
Total Flights with Requests	10,059	12,562	22,149
Total Requests	13,929	15,043	28,972
Percent of Requests with Observed Clearance	90.4%	88.7%	89.5%
Percent of Requests with Unable Response	3.0%	1.7%	2.3%

H.10.9 There were approximately 10,255 weather deviation requests during the sample period greater than or equal to 25-NM (half of the 50-NM lateral separation standard), about 65 percent of the total number of requests. Approximately 89 percent were observed to receive a clearance and 2.1 percent were observed to receive an “Unable” response.

H.10.10 There were approximately 22,403 weather deviation requests during the sample period greater than or equal to 15-NM (half of the 30-NM lateral separation standard), about 77 percent of the total number of requests. Approximately 90 percent were observed to receive a clearance and 2.3 percent were observed to receive an “Unable” response.

H.10.11 In addition to the weather deviation requests, the use of “Captain’s Authority” was investigated. The weather deviation procedures published for pilots in FAA Notices and in ICAO Doc 4444 address situations where the pilot cannot obtain ATC clearance, but must maneuver to avoid convective weather.

H.10.12 CPDLC messages with the downlink message element “DM 80” indicate an aircraft is deviating from the cleared route due to an urgent need. These messages were extracted from the archived CPDLC data for the one-year sample period.

H.10.13 Due to the variation in the phraseology used by pilots to indicate they are deviating using “Captain’s Authority,” frequently occurring key words were first observed. These words were then used

to extract the HF messages related to weather deviations for “Captain’s Authority” from the one-year sample of archived HF data.

H.10.14 **Table H- 11** summarizes the observed usage of “Captain’s Authority” during the one-year sample period. **Figure H- 8** shows the observed usage by month highlighting the counts of messages received via CPDLC and HF. Approximately 90 percent of the “Captain’s Authority” messages were received via HF.

Table H- 11. Observed Use of “Captain’s Authority” in New York Oceanic Airspace - June 2011 to May 2012

CPDLC	HF	Total
89	579	668

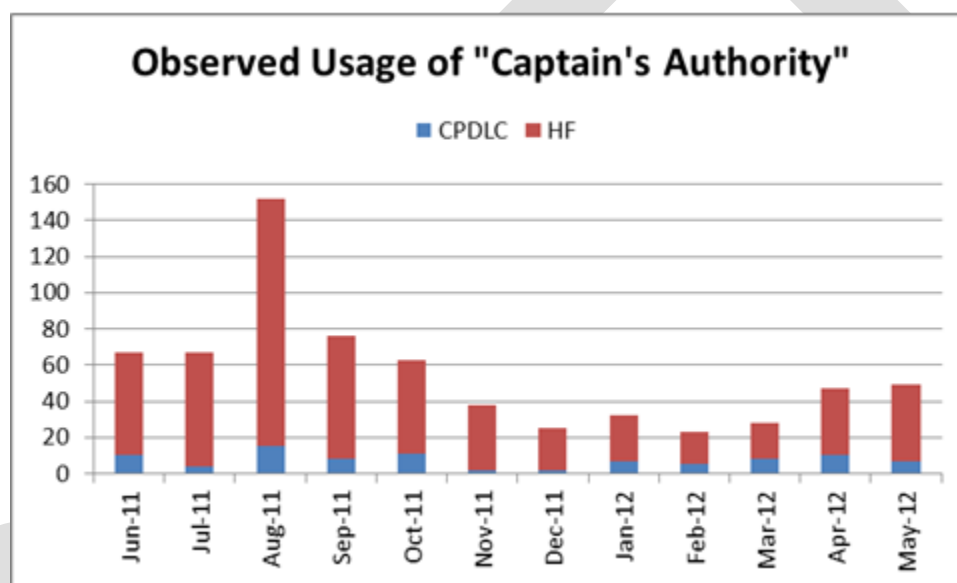


Figure H- 8. Observed usage of “Captain’s Authority” in New York oceanic airspace by month

H.10.15 Weather deviations will continue to be monitored using the archived CPDLC and HF messages.

H.11 Data Link Communication Performance

H.11.1 General

H.11.1.1 The ICAO NAT Systems Planning Group (SPG) adopted the First Edition of the Global Operational Data Link Document (GOLD) at its forty-sixth meeting in June 2010 (NAT SPG Conclusion 46/8). The GOLD replaces the Guidance Material for ATS Data Link Services in North Atlantic Airspace as regional guidance material for use by States and airspace users as the basis for operating ADS-C and

CPDLC in the NAT Region. The GOLD includes guidance material for data link service provision, operator preparation, aircraft equipage, controller and flight crew procedures, performance-based specifications for communications and surveillance, post-implementation monitoring, and corrective actions.

H.11.1.2 Appendix B of the GOLD provides the specifications for RCP types 240 and 400. The RCP type corresponds to the expiration time (ET), or the maximum time for the completion of the operational communication transaction after which the initiator is required to revert to an alternative procedure, for the respective set of specifications.

H.11.1.3 Appendix C of the GOLD provides to the specifications for required surveillance performance (RSP), types 180 and 400. The RSP type corresponds to the surveillance overdue delivery time (OT), or the maximum time for the successful delivery of surveillance data after which the initiator is required to revert to an alternative procedure, for the respective set of specifications.

H.11.1.4 The RCP/RSP specifications are derived mainly from safety assessment, but where appropriate they include criteria to support operational efficiency and orderly flow of air traffic. In these cases, the specification indicates the distinction between safety and efficiency. In general these specifications provide a means of compliance and support:

- a) Safety oversight of ATS provisions and operations;
- b) Agreements/contractual arrangements that ATS providers and aircraft operators make with respective CSPs;
- c) Operational authorizations, flight crew training and qualification;
- d) Design approval of aircraft data link systems; and
- e) Operational-monitoring, analysis, and exchange of operational data among regions and States.

H.11.1.5 The RCP and RSP specifications are comprised of four elements: time, continuity, availability, and integrity. Within the specifications for each element there are allocations for each of the four main data link system components: air traffic service provider (ATSP), communication service provider (CSP), aircraft system, and aircraft operator.

H.11.2 Data link time and continuity

H.11.2.1 ICAO Doc 9869 now contains the information previously covered in Appendix D of the GOLD; it provides guidance for post-implementation monitoring of the data link system according to the RCP/RSP specifications. It details the data points that are necessary to extract from the FANS 1/A aircraft communications addressing and reporting system (ACARS) messages to calculate the performance measures: actual communication performance (ACP), actual communication technical performance (ACTP), pilot operational response time (PORT), and ADS-C downlink latency; and to conduct the prescribed analysis.

H.11.2.2 The ADS-C downlink latency is assessed for all ADS-C downlink messages when monitoring RSP; however, a specific subset of CPDLC transactions is considered when monitoring RCP. Only uplink communications transfer messages and typical intervention messages such as climb clearances with a WILCO response are assessed. These messages are considered to be intervention messages critical to the communications used when applying reduced separation standards.

H.11.2.3 According to the guidance in the GOLD, the ACP, ACTP and PORT for applicable CPDLC transactions are required to meet the RCP 240 criteria when sent via satellite and VHF; and are

required to meet RCP 400 criteria when sent via HF. Similarly, the ADS-C downlink latency is required to meet RSP 180 criteria for ADS-C downlink messages sent via satellite and VHF; and is required to meet RSP 400 criteria when sent via HF.

H.11.2.4 **Table H- 12** summarizes the RCP 240 and RSP 180 specifications applicable for the application of the 50-NM longitudinal, 30-NM lateral and 30-NM longitudinal separation minima. The performance criteria associated with each prescribed performance measure are listed.

Table H- 12. Summary of GOLD data link performance requirements

Performance Measure	Proportion of Messages Required to Meet Criteria	RSP 180 Criteria (sec)	RCP 240 Criteria (sec)
ADS-C Latency	95.0%	90	--
	99.9%	180	--
ACTP	95.0%	--	120
	99.9%	--	150
ACP	95.0%	--	180
	99.9%	--	210
PORT	95.0%	--	60

H.11.2.5 **Table H- 13** presents a summary of the observed performance for the ADS-C downlink messages and CPDLC transactions applicable to RCP within the New York oceanic FIR during the recent analysis period from July to December 2012. The count of CPDLC transactions for each media type, satellite (SAT), VHF and HF includes only those in which that respective media type was used for both the uplink and downlink portion of the transaction. Approximately 1.43 percent of the transactions occurred using mixed media. The observed RCP for messages sent via HF media are not shown as only 3 CPDLC transactions occurred using pure HF media.

Table H- 13. Observed performance by data link media type in New York FIR

Media Type	Count of ADS-C Downlink Msgs	ADS-C 95%	ADS-C 99.9%	Count of CPDLC Transactions	ACTP 95%	ACTP 99.9%	ACP 95%	ACP 99.9%	PORT 95%
		RSP 180			RCP 240				
Aggregate	641,592	98.2%	99.3%	43,615	99.3%	99.5%	98.7%	99.1%	95.1%
SAT	505,182	98.1%	99.4%	39,326	99.4%	99.6%	98.8%	99.2%	95.2%
VHF	134,146	99.0%	99.4%	3,711	100%	100%	99.5%	99.5%	95.7%
		RSP 400			RCP 400				
HF	2,264	92.7%	95.1%	3	--	--	--	--	--

H.11.2.6 The cells colored in green highlight where the performance measures are met for observed performance in New York FIR during the aggregate period from July to December 2012. Likewise, cells colored in red highlight where the performance is not meeting the criteria, and the cells colored in yellow highlight where the 99.9% performance is nearly met at the “rule-of-thumb” between 99.0% and 99.9%.

H.11.2.7 The observed HF ADS-C performance does not meet the 95% criterion for RSP 400 during this period.

H.11.2.8 In anticipation of a formal process for RCP 240 and RSP 180 State approvals, the FAA Technical Center has developed methodologies to identify whether or not operations meet the 95% and 99.9% performance criteria. **Figure H- 9** shows the observed ADS-C latency performance over all media types for the five aircraft types that do not meet the 95% criterion for RSP 180 during the most recent 8-month period from July 2012 through February 2013 in New York oceanic airspace. These five aircraft types are B752, B753, B762, C17, and C5.

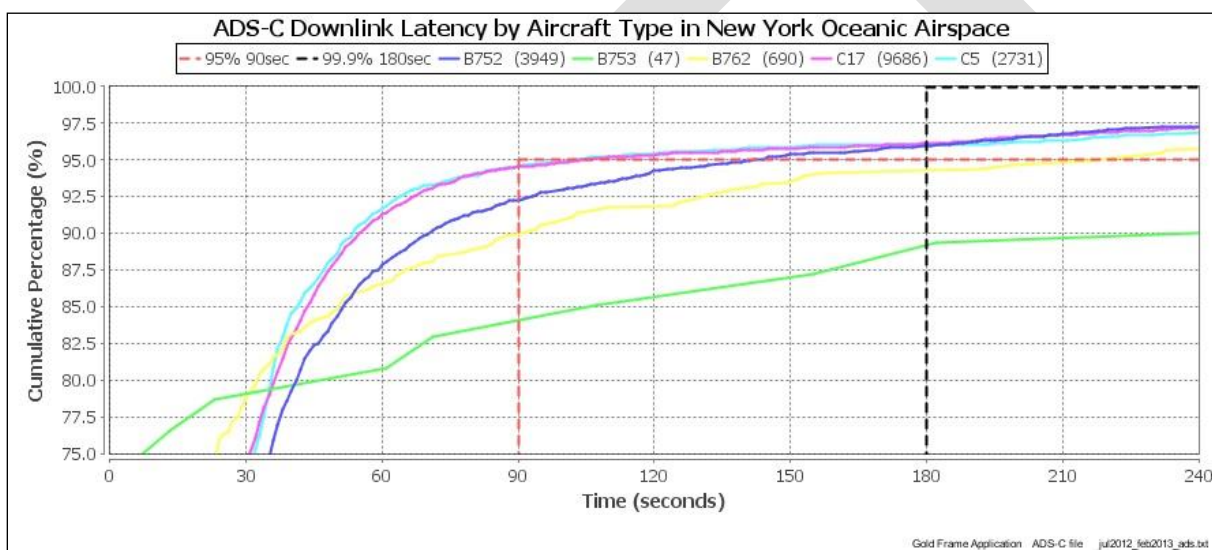


Figure H- 9. ADS-C downlink latency performance for aircraft types with observed performance below 95% Criteria – July 2012 through February 2013

H.11.2.9 **Table H- 14** presents the top 33 individual airframes, in terms of the number of ADS-C reports, observed in New York oceanic airspace from July 2012 to February 2013 that do not meet the 95% criterion for RSP 180. Each row in **Table H- 14** corresponds to unique airframe, but the individual airframe identifications are not provided and the operator information is de-identified. The observed performance levels at 90 seconds (95% criteria) and 180 seconds (99.9% criteria) are shown for each airframe in the last two columns, respectively, of **Table H- 14**.

Table H- 14. Top 33 airframes with ADS-C latency performance the RSP180 95% criterion

Operator Code	Aircraft Type	Count of ADS-C Reports	Observed Performance at 90 seconds	Observed Performance at 180 seconds
FF	B772	5,848	94.66%	97.85%
EE	A332	4,865	94.35%	95.10%
EE	A332	4,630	89.74%	90.96%
FFF	A345	2,858	94.17%	94.92%
LL	A333	1,152	93.51%	94.10%
A	B764	1,123	94.21%	97.09%
A	B764	1,109	94.41%	96.98%
A	B764	1,065	94.74%	96.90%
A	B764	797	94.89%	97.19%
GGG	A332	711	94.89%	98.53%
GGG	A332	643	93.70%	97.93%
L	A332	595	94.96%	98.75%
L	A333	592	94.43%	98.24%
L	A332	579	94.73%	97.63%
A	B772	553	92.59%	98.31%
HHH	B744	380	93.68%	98.02%
L	A333	363	94.86%	98.56%
A	B752	348	79.84%	86.49%
A	B772	298	94.56%	99.59%
A	B752	293	92.01%	97.50%
A	B772	292	94.86%	100.00%
L	A332	290	94.66%	97.99%
GG	A343	262	93.17%	93.84%
L	B763	248	89.73%	94.35%
A	B752	243	92.90%	96.94%
III	B772	241	88.04%	89.14%
JJJ	A332	238	76.91%	78.58%
KJK	MD11	238	92.02%	97.68%
LLL	B772	236	91.84%	98.49%
A	B752	233	92.49%	97.46%
A	B772	231	93.44%	98.89%
A	B752	231	94.40%	96.33%
A	B752	229	94.91%	96.74%

H.11.2.10 The data in [Figure H- 9](#) and [Table H- 14](#) are provided to demonstrate that there are operations that do NOT currently meet the RSP 180 and RCP 240 criteria in New York oceanic airspace. In the future, once the State approval process for RCP240 and RSP180 is formalized, operators will file the appropriate codes indicating RCP/RSP State approval in the flight plan. The FAA intends to make use of this flight plan information to identify operations that have State approval for RSP 180 and RCP 240 into the New York oceanic ATC and the Ocean21 system. This process will be similar to the treatment of the filed RNP specification information used to identify operations eligible for the application of the reduced separation.

H.11.3 Reported Data Link Outages

H.11.3.1 In Appendices B and C of the GOLD, the availability requirements of the RCP and RSP specifications are primarily allocated to the CSP level. [Table H- 15](#) summarizes the availability specifications for RSP 180 and RCP 240.

Table H- 15. Summary of CSP availability requirements for RCP Type 240 and RSP Type 180

Specification: RSP 180/D, Application: ADS-C, FMC WPR; and Specification: RCP 240/D, Application: CPDLC			
Component: CSP			
Availability parameter	Efficiency	Safety	Compliance means
Service availability (ACSP)	0.9999	0.999	Contract/service agreement terms
Unplanned outage duration limit (min)	10	10	Contract/service agreement terms
Maximum number of unplanned outages	4	48	Contract/service agreement terms
Maximum accumulated unplanned outage time (min/yr)	52	520	Contract/service agreement terms
Unplanned outage notification delay (min)	5	5	Contract/service agreement terms

H.11.3.2 The FAA Technical Center receives notifications of data link outages and degradations of service from the various communication service providers. Reasons for outages and degradations include service interruptions at the satellite and/or ground station level. These data are used to measure the availability of the system for New York oceanic airspace.

H.11.3.3 A majority of the recent service degradation reports are specific to the Iridium system and were caused by inclement weather affecting the Iridium ground station located in Phoenix, Arizona, US. It is not known how many flights using Iridium were affected by these degradations. However, less than one percent of all ADS-C downlink messages and CPDLC RCP transactions sent using satellite media during the recent analysis period from February to July 2012 were sent over the Iridium network.

H.11.3.4 The FAA Technical Center assesses the availability of the data link system for the New York oceanic airspace by accounting for the use of the various satellite and ground data link systems. The availability requirements listed in [Table H- 15](#) are used to monitor the availability in New York

oceanic airspace. The proportion of ADS-C reports received through the Iridium and Inmarsat satellite systems are used to weight the availability resulting from the reported outages.

H.11.3.5 **Figure H- 10** presents the weighted observed availability of the data link system for operations conducted within New York oceanic airspace. The proportion of operations using the Inmarsat and Iridium systems are 98.88 and 1.12 percent, respectively. These proportions are used to weight the reported outages and their effect on the data link system availability presented in **Figure H- 10**. Each reported outage is maintained for twelve calendar months in the availability performance statistic. For example, there was a reported outage on the Inmarsat satellite with duration of more than 13 hours in October 2011. Since the proportion of data link operations using the Inmarsat satellite system is very high in New York airspace, the data in **Figure H- 10** show the effects of this large outage through September 2012. The safety and efficiency criteria of 0.999 and 0.9999, respectively, are shown in the figure.

H.11.3.6 **Figure H- 11** presents the accumulated unplanned outage time for the data link system availability in New York oceanic airspace. These data are also weighted by the proportion of the operations using the different systems. The safety and efficiency criteria of 520 and 52 minutes per year, respectively, are shown in the figure. The duration from each reported outage is maintained for twelve calendar months in the availability performance statistic. The reported outage in October 2011 from the Inmarsat system with duration of more than 13 hours was the main cause of the availability performance not meeting the safety criterion for many of the months shown in **Figure H- 11**.

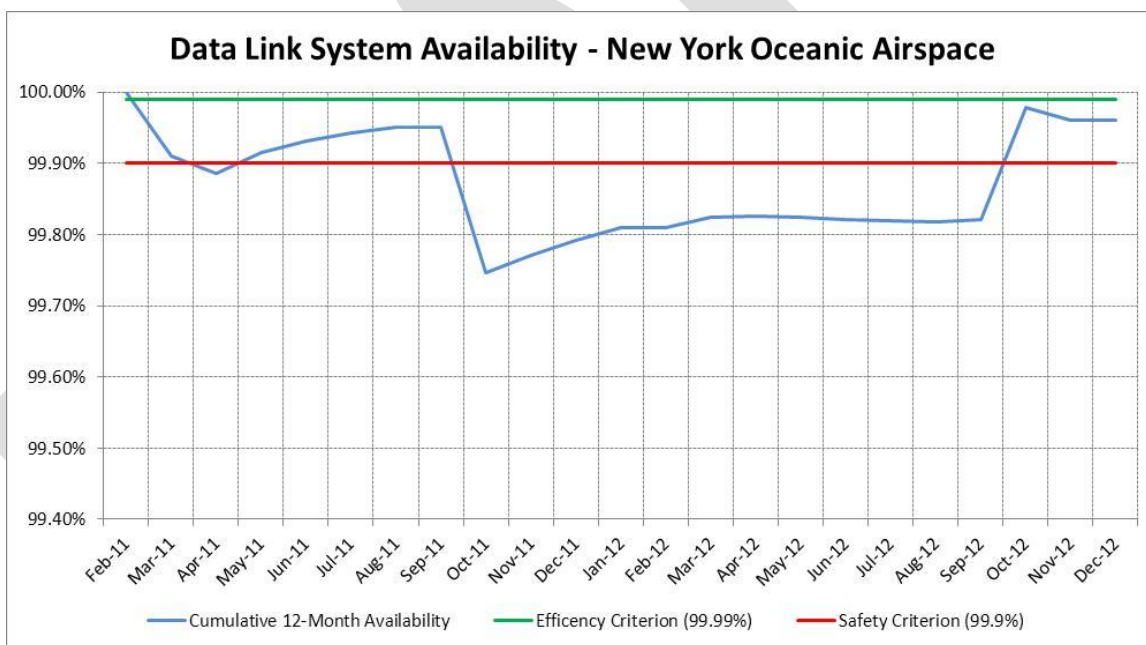


Figure H- 10. Data Link System Availability – New York Oceanic Airspace

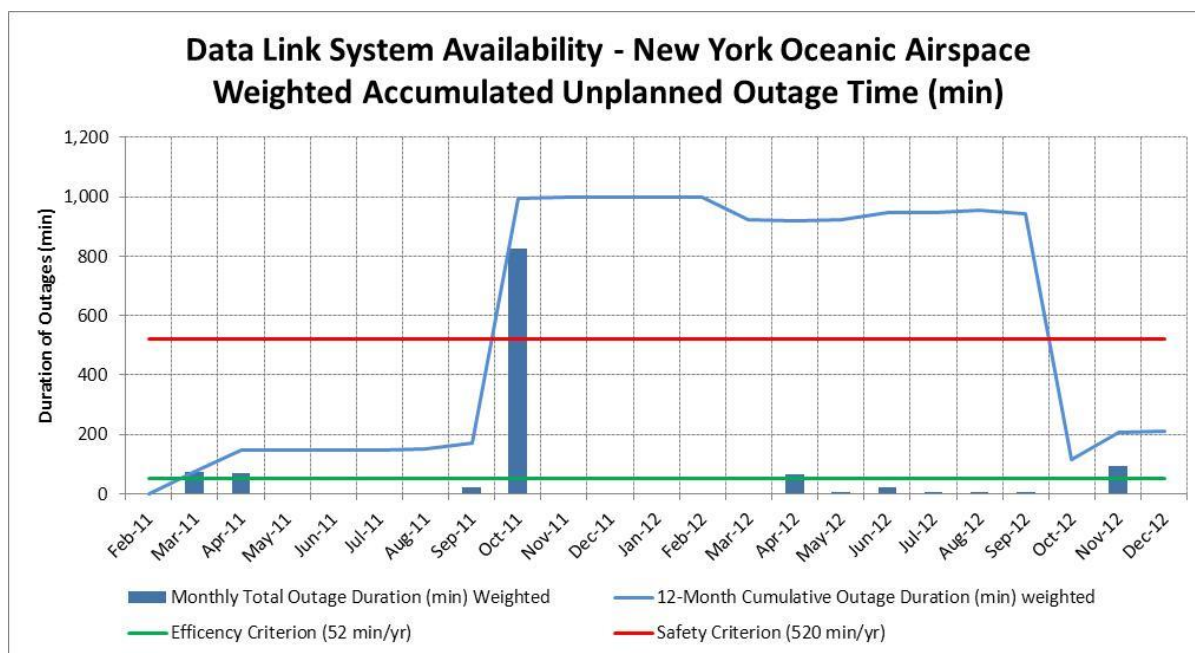


Figure H- 11. Data Link System Availability – Weighted Accumulated Unplanned Outage Time (minutes)

H.11.3.7 Since the implementation of ADS-based separation standards in the Oakland FIR, periods of poor performance of the data link communications service have been observed. During these periods, the FAA has suspended the use of ADS-based separation standards in the Oakland FIR. The use of ADS-based separation standards in the Oakland FIR was limited after the communication service was found to exhibit inadequate reliability.

H.11.4 Overdue ADS Periodic Reports

H.11.4.1 The FAA Technical Center examines the aircraft ADS-C periodic reports in the archived data and identifies cases of overdue reports. The numbers of flights with at least one overdue ADS-C periodic report were examined. Further analyses are done to examine the automated/manual controller response to an overdue report. [Table H- 16](#) contains a listing of the number of flights using ADS-C with at least one missing ADS-C periodic report by month over the time period of June 2011- May 2012.

Table H- 16. Overdue ADS-C Reports in New York oceanic airspace

Month	Number of Operations with Overdue ADS-C Reports	Number of Operations Using ADS-C	Proportion
Jun-11	140	4624	3.03%
Jul-11	111	5083	2.18%
Aug-11	94	5392	1.74%
Sep-11	133	4842	2.75%
Oct-11	110	5482	2.01%

Month	Number of Operations with Overdue ADS-C Reports	Number of Operations Using ADS-C	Proportion
Nov-11	115	4765	2.41%
Dec-11	189	6015	3.14%
Jan-12	181	5887	3.07%
Feb-12	245	5068	4.83%
Mar-12	200	5550	3.60%
Apr-12	165	5635	2.93%
May-12	132	5449	2.42%
Average	151.25	5316	2.84%

H.11.4.2 The summary data provided in [Table H- 16](#) show that approximately 2.8 percent or 151 flight operations per month in the New York oceanic airspace have at least one overdue ADS-C report.

H.11.4.3 The longitudinal collision risk model used in this safety assessment considers the case where an ADS report takes longer than 3 minutes and is considered to be lost (see [Table H- 12](#)). ICAO Doc 9689 conservatively assumed that an ADS report would be lost 5 percent of the time. The longitudinal safety assessment contained in this document also assumes a 5 percent rate for this case, as the empirical data still show this to be a conservative estimate.

H.12 Ocean21 Decision-Support Features Important to the Application of the Reduced Horizontal Separation Standards

H.12.1 The Ocean21 system provides many enhancements to the application of ATC in New York oceanic airspace. Several of these are particularly important to use of the 50-NM longitudinal, 30-NM lateral, and 30-NM longitudinal separation minima. It is not possible to separate the effect of the ATC automation and decision support tools from the data. Therefore, it can be concluded that the Ocean21 system (or similar functioning system) must also be present when applying the reduced separation minimum.

Ocean21 System Display

H.12.2 The system aids controller situational awareness and decision making using a full-color display which provides important descriptive data for each aircraft, including indications of separation minima which may be approved for eligible pairs of aircraft. The display presents the full geographic extent of the controller's area of responsibility, as well as adjacent areas.

Ocean21 Conflict Probe

H.12.3 Upon receipt of an ADS-C report from an aircraft or controller request for examination of a modification to an aircraft's current flight plan, the system automatically looks for conflicts between aircraft trajectories, or violations of applicable separation minima, between the aircraft and all others in the airspace, using a preset interval look-ahead time. If a conflict is uncovered, the controller is notified

on the Ocean21 display by means of flashing colored leader lines from the two aircraft in conflict, with intersection of the lines at the projected point of conflict. The probe is informed not only by previously received ADS position reports from all aircraft under ATC, but also by meteorological forecasts which are updated appropriately to the latest version received at the New York ARTCC.

H.13 Parameters for the Collision Risk Models

H.13.1 General

H.13.1.1 Several of the collision risk parameters are common to both the lateral and longitudinal collision risk models, provided in equations 1 and 2, respectively. The next sections provide the values of each parameter needed to estimate the collision risk associated with the reduced horizontal separation standards.

H.13.2 Parameters Common to the Lateral and Longitudinal Collision Risk Models

H.13.2.1 Aircraft length, wingspan and height - λ_x , λ_y and λ_z

H.13.2.1.1 The length, wingspan and height of the average aircraft observed in New York oceanic airspace are obtained from the aircraft types contained in the KYA study. The length, wingspan, and height of the average aircraft are calculated using a weighted average based on the proportion of aircraft types observed in the airspace. [Table H- 17](#) shows the aircraft length, wingspan, and height, expressed in NM, of the aircraft types observed in the airspace. The weighted average aircraft length, wingspan, and height, expressed in NM, are 0.03087, 0.002826 and 0.00876, respectively.

Table H- 17. Weighted Size of the Aircraft Eligible for the Reduced Separation Standards in New York oceanic airspace

Aircraft Type	Proportion	Length (NM) λ_x	Wingspan (NM) λ_y	Height (NM) λ_z
B763	15.33%	0.005028	0.0043595	0.001456
A332	11.59%	0.004085	0.004175	0.001239
A320	8.40%	0.001885	0.0017107	0.00059
B744	8.32%	0.003514	0.0031959	0.000959
B772	8.15%	0.003102	0.0029664	0.000901
A343	6.07%	0.00231	0.002187	0.000611
A346	5.26%	0.002367	0.0019948	0.000544
B752	4.91%	0.001387	0.0011172	0.000399
A333	4.91%	0.001868	0.001768	0.000494
B738	4.70%	0.001109	0.0009632	0.000354
B77W	3.00%	0.001324	0.0011614	0.000333
MD11	2.60%	0.000952	0.0008035	0.000274

Aircraft Type	Proportion	Length (NM) λ_x	Wingspan (NM) λ_y	Height (NM) λ_z
B762	1.53%	0.000445	0.0004366	0.000146
B737	1.39%	0.000278	0.0002842	0.000104
B764	1.35%	0.000495	0.0004185	0.000136
A319	1.14%	0.000231	0.0002329	8.04E-05
B77L	0.89%	0.000339	0.0003449	9.91E-05
GLF5	0.84%	0.000147	0.0001424	3.75E-05
Average		0.030868	0.0282622	0.008758

H.13.2.1.2 As described in [section H.3](#), New York oceanic airspace can be considered as separated into two sub-regions, WATRS and NAT. It is important to note that, there are number of published routes in WATRS, both north-south and east-west, whereas routings are flexible in the NAT portion of New York oceanic airspace. Since the airspace is considered as two separate sub-regions, the average aircraft size differs. The average aircraft dimensions for each region are detailed in [Table H- 18](#).

Table H- 18. Weighted Aircraft Size of Operations Eligible for the Reduced Separation Standards in New York Oceanic Airspace, WATRS, and NAT regions.

Airspace	Length (NM) λ_x	Wingspan (NM) λ_y	Height (NM) λ_z
New York Oceanic (ZNY)	0.03087	0.02826	0.00876
WATRS	0.02760	0.02507	0.00808
NAT	0.03402	0.03117	0.00939

H.13.2.2 Probability That Two Aircraft Assigned to the Same Flight Level Are in Vertical Overlap: $P_A(0)$

H.13.2.2.1 The probability of vertical overlap required to estimate longitudinal risk is that associated with two co-altitude aircraft. The value used in this safety assessment is 0.471. This value is based on the current value used for NAT airspace, 0.48, but is adjusted for the difference in the average aircraft heights (0.00876/0.00892).

H.13.2.3 The Average Relative Vertical Speed of Two Aircraft Assigned to the Same Flight Level: $\overline{|\dot{z}|}$

H.13.2.3.1 As has been the case in all recent safety assessments conducted to support separation changes in the Pacific and North Atlantic, the value used in this document is 1.5 knots. This value also reflects the effect of the RVSM on height-keeping performance.

H.13.3 Parameters Used Only in Estimation of Lateral Risk

H.13.3.1 Average absolute relative along-track speed of two-aircraft as they pass on parallel

tracks - $\overline{|\dot{x}|}$

H.13.3.1.1 Aircraft operations on parallel tracks are independent of application of Mach number technique or any other actions by ATC to regulate the relative speed between aircraft. As a result, the relative speed between a typical pair of co-altitude aircraft on adjacent tracks reflects the range of speeds of individual aircraft in the airspace. The FAA Technical Center assembled the reported ground speeds, obtained from the ADS-C basic reports, from 298,669 ADS-C operations in New York oceanic airspace over the period January through May 2012.

H.13.3.1.2 Using the uncorrelated-speed property of aircraft assigned to the same flight level on parallel routes, the absolute value of each possible difference in speed are weighted according to the proportions of entries. These weighted speed differences are averaged, producing a value of 27 knots for the average relative along-track speed of a pair of co-altitude on laterally adjacent routes.

H.13.3.2 Average absolute relative cross-track speed between aircraft pairs operating on

tracks nominally separated by S_y - $\overline{|\dot{y}(S_y)|}$

H.13.3.2.1 This parameter describes the relative speed of two aircraft as they lose all planned lateral separation. Since the basic track-keeping accuracy of aircraft equipped with navigation systems using GNSS-derived positioning is widely regarded as precluding the loss of 30-NM lateral separation due to normal navigational performance, the most reasonable circumstance associated with an event is a waypoint insertion error. While there are Ocean21 safeguards against the occurrence of this type of event - conflict probe examination of filed flight plan and establishment of a 5-NM lateral deviation event contract for all aircraft capable of participating in the application of the 30-NM separation minima – the estimation of the lateral risk proceeds with a value of 36 knots for the relative across-track speed parameter. This value corresponds to the lateral speed of an aircraft relative to correct track, which would result in a lateral error of 30-NM between two waypoints separated by a typical distance in New York oceanic airspace. The assumed average aircraft speed used was 480 knots, and the typical distance between two consecutive waypoints in New York oceanic airspace was 400-NM.

H.13.3.3 Same- and Opposite-Direction Lateral Occupancies – $E_y(\text{same})$ and $E_y(\text{opp})$

H.13.3.3.1 Occupancy is a measure of exposure of aircraft to one another within an airspace. While occupancy does generally increase as traffic level increases, there is not a one-to-one correspondence between a measure of traffic activity – number of annual flights, for example – and the value of airspace occupancy. Rather, occupancy increases as more aircraft operate at the same time on the laterally adjacent flight paths, increasing the chance that there might be a proximate aircraft.

H.13.3.3.2 Occupancy is a dimensionless number, computed, in the lateral case, as twice the ratio of the number of aircraft on a track which are within an arbitrary longitudinal sampling interval of a typical aircraft on a laterally adjacent track. Lateral occupancy is estimated separately for aircraft flows operating in the same direction on each of two parallel tracks and for flows operating on reciprocal headings on the tracks – hence the terms “same-direction” and “opposite-direction” lateral occupancies.

H.13.3.3.3 The product of the ratio $(2\lambda_x/S_x)$ and $E_y(\text{same})$ is twice the probability of longitudinal overlap, P_x , for co-altitude same-direction aircraft pairs on parallel routes; the same ratio multiplied by $E_y(\text{opp})$ produces the comparable opposite-direction probability.

H.13.3.3.4 The same and opposite direction lateral occupancy values were estimated from a 6-month sample of Ocean21 data including May, July, September and November 2011 and January and March 2012. A lateral pair was identified for an aircraft when a second aircraft crossed over the adjacent airway fix located on a parallel route separated laterally by 50-NM, at the same flight level within 15 minutes of the first aircraft. The same and opposite direction lateral occupancy values used in the safety assessment are 0.0641 and 0.0005, respectively.

H.13.3.4 Probability That Two Aircraft Lose Planned 30-NM Lateral Separation – $P_y(30)$

H.13.3.4.1 The RNP 4 is the required lateral navigation performance for the application of the 30-NM lateral separation standard. The navigation performance and the reports of gross lateral errors are combined to estimate the lateral overlap probability.

H.13.3.4.2 In the past, aircraft lateral deviations have been modeled as Double-Double Exponential (DDE) random variables. A probability density function for the DDE distribution is given in Eq. (4) as:

$$f(x; \alpha, \lambda_1, \lambda_2) = \frac{1-\alpha}{2\lambda_1} e^{-\frac{|x|}{\lambda_1}} + \frac{\alpha}{2\lambda_2} e^{-\frac{|x|}{\lambda_2}} \text{ where } 0 < \alpha < 1, \text{ and } 0 < \lambda_1 < \lambda_2 \quad (4)$$

H.13.3.4.3 The DDE density is a weighted sum of two Double Exponential densities, one often called the “core” density, and the other known as the “tail” density. The weights are $1-\alpha$ and α ; the core density, $\frac{1}{2\lambda_1} e^{-\frac{|x|}{\lambda_1}}$, describes typical lateral deviations from the centerline of the aircraft’s intended route; and the tail density, $\frac{1}{2\lambda_2} e^{-\frac{|x|}{\lambda_2}}$, describes atypical lateral deviations from the centerline of the intended route.

H.13.3.4.4 The core density is determined by 4-NM / 95 percent containment. The parameter λ_1 representing the typical lateral errors can be estimated directly from the RNP value for the airspace. In this case, λ_1 is estimated to be 1.335-NM.

H.13.3.4.5 The tail density is determined by the frequency of the atypical lateral errors reported in the airspace. It has been shown using principles of differential calculus that the overlap probability can be approximately maximized by selecting a λ_2 equal to the designated separation minimum, in this case 30-NM. The contribution of the tail density is determined by α . The frequency of lateral errors described in [section H.8](#) gives the value for α as 7.38×10^{-5} .

H.13.3.4.6 The probability of lateral overlap is determined by self-convolving the density given in (4) with the parameter estimates given above. The resulting value for the probability of lateral overlap used in this safety assessment is 5.13×10^{-8} .

H.13.3.4.7 **Table H- 19** provides a listing of the lateral collision risk model parameter values used in the safety assessment for the implementation of the 30-NM lateral separation standard in New York oceanic airspace.

Table H- 19. Parameter Values for the Lateral Collision Risk Model for the 30-NM Lateral Separation Standard in New York oceanic airspace

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
$ \bar{x} $	Average absolute relative along track speed between aircraft on same direction routes	27 knots	Estimated from ADS-C reports in traffic sample
$ \bar{V} $	Average absolute aircraft air speed	480 knots	
$ \bar{y}(30) $	Average absolute relative cross track speed	36 knots	
$ \bar{z} $	Average absolute relative vertical speed of an aircraft pair that have lost all vertical separation	1.5 knots	
S_x	Length of longitudinal window used to calculate occupancy	120-NM	
λ_x	Average aircraft length	0.0309-NM	Weighted average based on traffic sample
λ_y	Average aircraft wing-span	0.0283-NM	Weighted average based on traffic sample
λ_z	Average aircraft height with undercarriage retracted.	0.0088-NM	Weighted average based on traffic sample
$P_z(0)$	Probability that two aircraft which are nominally at the same level are in vertical overlap.	0.471	Value from NAT adjusted for difference in aircraft heights
N_{ay}	Number of fatal accidents per flight hour due to loss of lateral separation.	Calculated	

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
S_y	Lateral separation minimum	30-nm	
$P_y(S_y)$	Probability that two aircraft which are nominally separated by the lateral separation minimum are in lateral overlap.	5.13×10^{-8}	Determined from the RNP requirement and the observed frequency of lateral errors in ZNY airspace
$E_y(\text{same})$	Same direction lateral occupancy	0.0641	Average value estimated from traffic movement sample
$E_y(\text{opp})$	Opposite direction lateral occupancy	0.0005	Average value estimated from traffic movement sample

H.13.4 Parameters Used Only in Estimation of Longitudinal Risk

H.13.4.1 Assumed average ground speed of aircraft 1, V1, and aircraft 2, V2

H.13.4.1.1 The assumed average speed of aircraft 1, V1, and aircraft 2, V2, is 480 knots. This is also a value used in the vertical collision risk model for New York oceanic airspace.

H.13.4.2 Average aircraft wingspan or length - λ_{xy}

H.13.4.2.1 The average aircraft wingspan or length, λ_{xy} , is taken to be the larger of either the average wingspan or length for New York oceanic airspace. This value, as provided in [Table H- 17](#), is 0.03087 -NM.

H.13.4.3 Scale parameter for the speed error distribution - λ_v

H.13.4.3.1 The speed error distribution is used to model variations in speed around the nominal speed. The speed error is modeled as in Appendix 1 of Doc 9689 which used a scale parameter, λ_v with a value of 5.82 knots. This value was based on a sample of 10,318 ADS reports during the years 1994 and 2000.

H.13.4.4 ADS-C report interval - T

H.13.4.4.1 Several ADS-C reporting rates have an effect on the longitudinal collision risk and are considered in this safety assessment. The required reporting rate specified in ICAO Doc 4444 for the use of the 50-NM longitudinal separation standard is 27 minutes. In addition to the 27 minute reporting rate,

26, 25, 24, 23, 22, and 20 minute reporting rates are examined to observe the effect on the collision risk estimate.

H.13.4.4.2 The required reporting rate specified in ICAO Doc 4444 for the use of the 30-NM longitudinal separation standard is 14 minutes. In addition to the 14 minute reporting rate, 9, 10, 11, 12, and 13 minute reporting rates are considered. A more frequent ADS-C reporting of position will typically yield a lower risk of collision.

H.13.4.5 Controller intervention buffer - τ

H.13.4.5.1 Table H- 4 through Table H- 6 provide the components of the controller intervention buffer contained in ICAO Doc 9689. The safety assessment in this document utilizes empirical data for the CPDLC uplink data link portion of the controller intervention buffer. Table H- 20 contains the empirical distribution obtained from operations in New York airspace from June 2011 through May 2012. The data in Table H- 20 show that more than 99 percent of the uplink CPDLC messages were delivered within 90 seconds.

Table H- 20. New York oceanic airspace Uplink CPDLC Transit Time Data, June 2011 – May 2012

Uplink Time (Seconds)	Count	Relative Frequency	Cumulative Frequency
$0 \leq X < 30$	68,084	95.86%	95.86%
$30 \leq X < 60$	1,760	2.48%	98.34%
$60 \leq X < 90$	838	1.18%	99.52%
$90 \leq X < 120$	228	0.32%	99.84%
$120 \leq X < 150$	63	0.09%	99.93%
$150 \leq X < 180$	29	0.04%	99.97%
$X \geq 180$	22	0.03%	100.00%
Total	71,024		

H.13.4.6 Cross-track and along-track position error distributions

H.13.4.6.1 A double exponential distribution is used for the aircraft along-track and cross-track position errors. The actual navigation performance for GNSS aircraft uses a scale parameter, $\lambda = \frac{k}{-\ln(0.05)}$, where $k = 0.3$. The navigation performance for operations eligible for the reduced longitudinal separation are also modelled with the required navigation performance, either $k = 4$ or $k=10$, which means 95 percent of the time operations are conducted within 4-NM or 10-NM, respectively of route centerline.

H.13.4.6.2 To demonstrate the effect the modelled lateral path keeping performance has on the longitudinal collision risk estimate, both the RNP and observed navigation performance are considered.

H.13.4.6.3 The use of GNSS in determining aircraft position produces highly accurate results. In turn, these accurate position estimates produce smaller lateral errors from course and lower across track velocities. Smaller lateral errors produce higher values of lateral overlap probability, thus increasing the risk of collision in the event that airplanes lose their assigned longitudinal separation. This “navigation paradox” – improvements in navigation in one dimension increase collision risk in another – is well known. Its presence in the application of a reduced longitudinal separation minimum is evident in the risk estimates.

H.13.4.7 Number of aircraft pairs per hour, NP

H.13.4.7.1 The number of aircraft pairs expected to need ATC intervention per hour, NP, set equal to 1. The chosen value of NP is considered to be very conservative.

H.13.4.8 Table of longitudinal collision risk parameters

H.13.4.8.1 [Table H- 21](#) contains a summary of the longitudinal collision risk model parameters used in the safety assessment for the 50-NM and 30-NM longitudinal separation minima in New York oceanic airspace.

Table H- 21. Longitudinal Collision Risk Parameters for New York oceanic airspace

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
V1	Assumed average ground speed of aircraft 1	480 knots	
V1	Assumed average ground speed of aircraft 2	480 knots	
λ_{xy}	Average aircraft wingspan or length	0.0308-NM	Estimated from New York traffic sample data
λ_v	Scale parameter for speed error distribution	5.82 knots	ICAO Doc 9689 Appendix 1
T	ADS-C periodic report rate	50-NM Longitudinal Separation; Varies - 20, 22, 23, 24, 25, 26, 27 minutes considered	
		30-NM Longitudinal Separation; Varies – 9, 10, 11, 12, 13, and 14 minutes considered	
τ	Controller intervention buffer.	3 cases (see Table H- 4 through Table H- 6) with empirical data for ZNY CPDLC Uplink in Table H- 20	ICAO Doc 9689 Appendix 1

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
NP	Number of aircraft pairs per hour	1	Conservative estimate

H.14 Estimation of Lateral Risk and Comparison to the TLS

H.14.1 Using the parameter values defined in [section H.13](#) and the lateral collision risk model stated in equation (1), the estimate of lateral collision risk for RNP 4 ADS-C aircraft operating in New York oceanic airspace with a 30-NM lateral separation standard is 0.52×10^{-9} fatal accidents per flight hour (fafh). This value is below the ICAO-endorsed TLS value applicable to judging the safety of the lateral separation minimum in international airspaces, 5.0×10^{-9} fafh due to the loss of planned lateral separation.

H.15 Estimation of Longitudinal Risk and Comparison to the TLS

H.15.1 Using the parameter values defined in [section H.13](#) and the longitudinal collision risk model stated in equation (2), the estimate of longitudinal collision risk for ADS-C aircraft operating in New York oceanic airspace with a 50-NM longitudinal separation standard varies with the assumed navigation performance and ADS-C reporting rate as shown in [Figure H- 12](#).

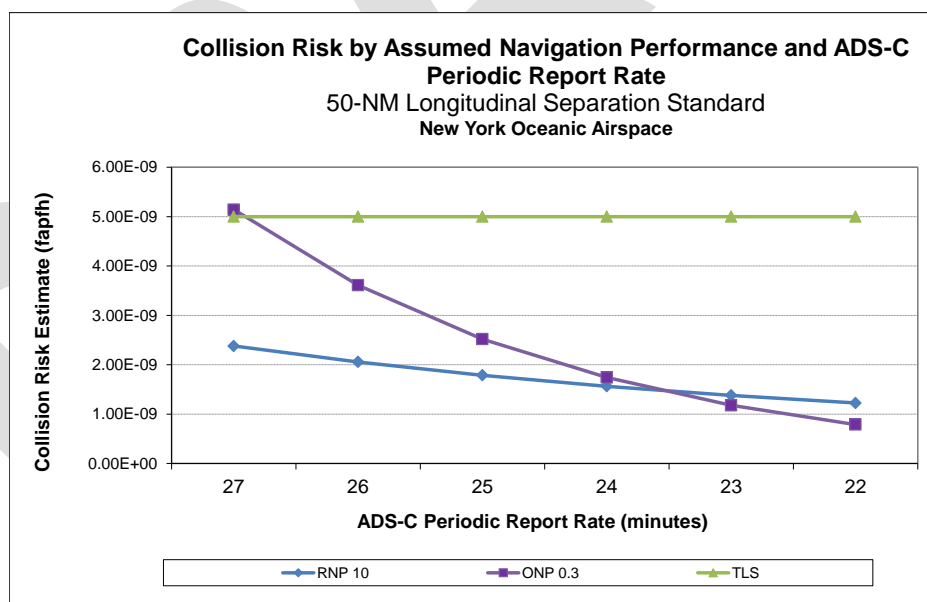


Figure H- 12. Longitudinal Collision Risk by ADS-C Report Rate and Assumed Navigation Performance – 50-NM Longitudinal Separation Minimum

H.15.2 The results shown in [Figure H- 12](#) demonstrate the differences in the estimates of longitudinal risk under various periodic report rates and assumed navigation performance. The first case,

labelled 'RNP 10', assumes the required navigation performance for all operations and is shown with the blue line in [Figure H- 12](#). The second case, labeled 'ONP 0.3', assumes the eligible operations use GNSS for navigation.

H.15.3 The reporting interval required for ADS-C/CPDLC RNP 10 aircraft is provided in ICAO Doc 4444 as 27 minutes. Due to limitations of the ADS-C functionality, the reporting interval provided to the aircraft from the ground system uplink message must be a multiple of 8. This means that the reporting interval must be no greater than 1600 seconds, or 26.67 minutes. [Figure H- 12](#) shows that a reporting interval of 26.67 minutes provides a risk estimate lower than the TLS for the application of the 50-NM longitudinal separation minimum in New York oceanic airspace. However, the current report interval assigned to ADS-C aircraft that do not indicate RNP 4 in the filed flight plan is 1216 seconds, or roughly 20 minutes. A 20-minute ADS-C report interval produces risk estimates below the TLS for both cases shown in [Figure H- 12](#).

H.15.4 Using the parameter values defined in [section H.13](#) and the longitudinal collision risk model stated in equation (2), the estimate of longitudinal collision risk for ADS-C aircraft operating in New York oceanic airspace with a 30-NM longitudinal separation standard varies with the assumed navigation performance and ADS-C reporting rate as shown in [Figure H- 13](#).

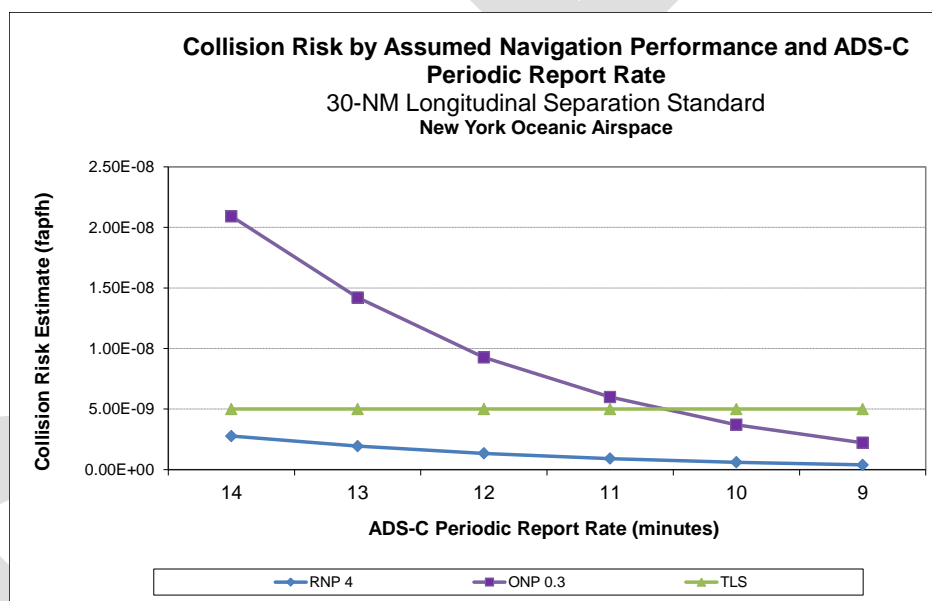


Figure H- 13. Longitudinal Collision Risk by ADS-C Report Rate and Assumed Navigation Performance – 30-NM Longitudinal Separation Minimum

H.15.5 The data shown in [Figure H- 13](#) demonstrates the differences in the estimates of longitudinal risk under various periodic report rates and assumed navigation performance. The first case assumes the required navigation performance (RNP 4) for all operations and is shown with the blue line in [Figure H- 13](#). The purple line with the label 'ONP 0.3' in [Figure H- 13](#) shows the risk estimates when all operations use GNSS for navigation. Therefore, the purple line indicating all operations using GNSS, labelled as 'ONP 0.3', is the choice for this safety assessment.

H.15.6 Assuming that all operations using GNSS have an observed navigation performance within 0.3 NM of route centerline, the longitudinal collision risk estimate is 3.70×10^{-9} fapfh with a 10-minute ADS-C periodic report rate. Therefore, the results from this safety assessment show that an ADS-C periodic report rate of 10 minutes provide an acceptable estimate of collision risk for the implementation of the 30-NM longitudinal separation standard in New York oceanic airspace. This value is below the ICAO-endorsed TLS value applicable to judging the safety of the longitudinal separation minimum in international airspaces, 5.0×10^{-9} fapfh due to the loss of planned longitudinal separation.

— END —

