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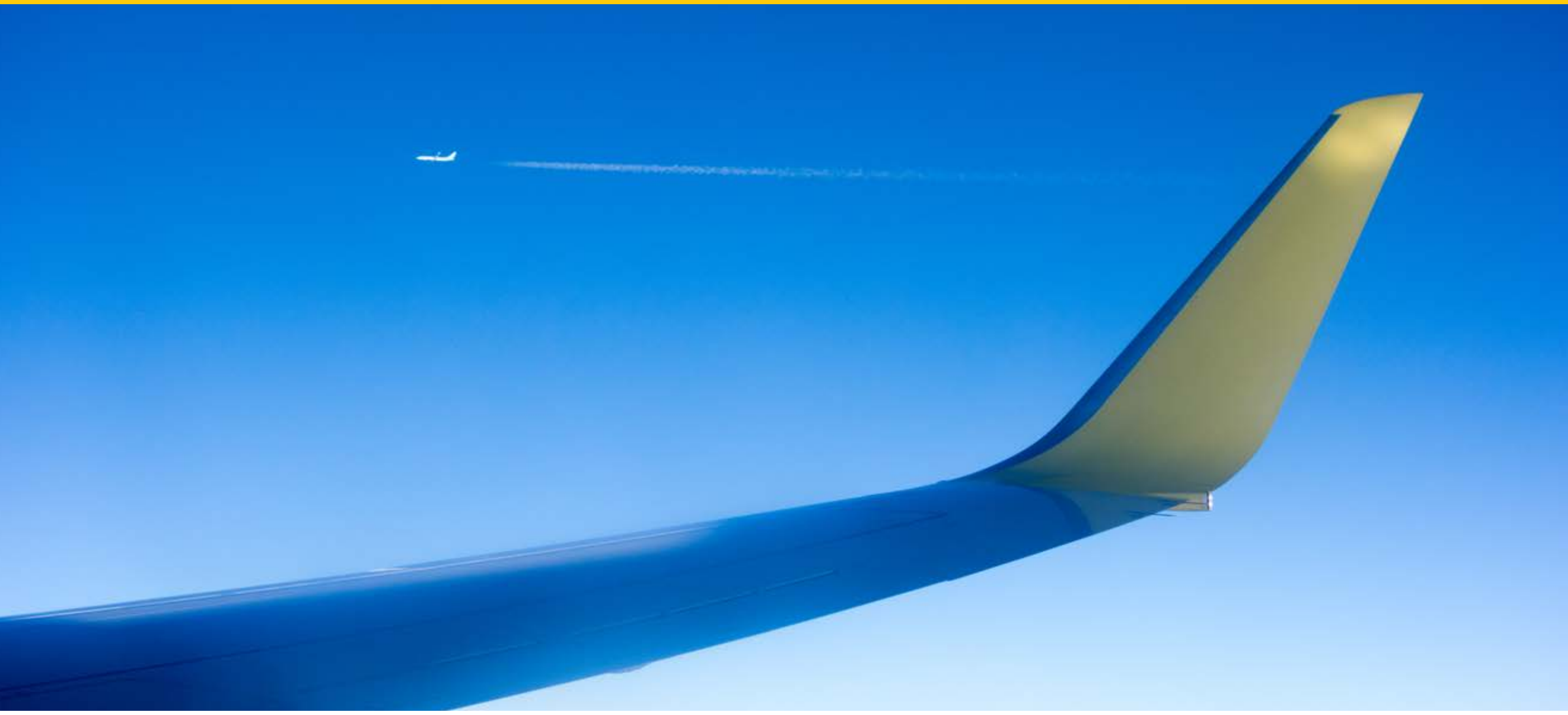
Doc 10063

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

First Edition, 2017



Approved by and published under the authority of the Secretary General

INTERNATIONAL CIVIL AVIATION ORGANIZATION

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AMENDMENTS

Amendments are announced in the supplements to the *Products and Services Catalogue;* 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.

RECORD OF AMENDMENTS AND CORRIGENDA

AMENDMENTS		
No.	Date	Entered by

CORRIGENDA		
No.	Date	Entered by

FOREWORD

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.

The 2011 publication of the first edition of the manual entitled *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) provides guidance on the establishment of such procedures and practices to support the 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. Hence, the ICAO Separation and Airspace Safety Panel (SASP) set out to develop a manual analogous to Doc 9937 as a means of assisting States and regions to standardize monitoring activities supporting performance-based horizontal separation minima.

This manual is the result of the SASP work, and should be considered to be supporting material to the *Safety Management Manual* (SMM) (Doc 9859). The proactive safety performance monitoring and measurement guidance provided in this manual can satisfy the safety assurance requirements provided in Annex 19 — *Safety Management* to the Convention on International Civil Aviation. In developing the material contained herein, the SASP relied upon the experience of experts from its Member States that had prior experience in developing relevant procedures and practices. It should be noted that Australia, New Zealand, Singapore and the United States have developed the *Asia/Pacific Region En-Route Monitoring Agency (EMA) Handbook*, and modified portions of that document are reproduced herein. Contributions by other regions, agencies and organizations are anticipated as the document matures and experience is gained.

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:

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GLOSSARY

DEFINITIONS

When the following terms are used in this manual, they have the meanings indicated below.

Note.— Where an asterisk appears beside a term, the term has already been defined as such in Annexes and Procedures for Air Navigation Services (PANS).

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

Note.— The Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM) *(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 secondary surveillance radar (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.

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.

****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.

Note 1.— The aircraft identification does not exceed seven 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 the document entitled Designators for Aircraft Operating Agencies, Aeronautical Authorities and Services (*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.

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

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.

***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.

***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.

***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.

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.

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.

***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.

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

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.

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.

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 take-off 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. One possibility for a region is to define an LLD as any lateral deviation with a magnitude at least two times the required navigation performance (RNP) specification associated with the smallest lateral separation minimum possible. In airspace where RNP is not applicable, an LLD should be considered to be a lateral deviation with magnitude greater than or equal to half the lateral 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 (APAC) Region.

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

Navigation specification. A set of aircraft and flight crew 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.— The Performance-based Navigation (PBN) Manual, *Volume II* (*Doc 9613) contains detailed guidance on navigation specifications.*

(Refer to Doc 9613, Volume 1 — *Concept and Implementation Guidance*, Explanation of Terms).

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 centres 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.

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.

****Procedural separation.*** The separation used when providing procedural control.

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.

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.

***State of Manufacture.** The State having jurisdiction over the organization responsible for the final assembly of the aircraft.

***State of Registry.** The State on whose register the aircraft is entered.

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 the document entitled 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.

***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.

ACRONYMS

When the following abbreviations are used in this manual, they have the meanings indicated below.

ACARS	Aircraft communication addressing and reporting system
ACP	Actual communication performance
ACTP	Actual communication technical performance
ADS	Automatic dependent surveillance
ADS-B	Automatic dependent surveillance – broadcast
ADS-C	Automatic dependent surveillance – contract
ANSP	Air navigation services provider
APANPIRG	Asia/Pacific Air Navigation Planning and Implementation Regional Group
APAC	Asia/Pacific
ARTCC	Air Route Traffic Control Center
ASP	Actual surveillance performance
ATC	Air traffic control
ATM	Air traffic management
ATS	Air traffic services
BRG	Bearing
CAA	Civil Aviation Authority
CMA	Central Monitoring Agency
CNS	Communication, navigation and surveillance
CPDLC	Controller-pilot data link communication
CRA	Central Reporting Agencies
CRM	Collision risk model
CSP	Communication service provider
DCPC	Direct controller-pilot communication
DDE	Double-double exponential
DE	Double exponential
DLMA	Data Link Monitoring Agency
EMA	En-Route Monitoring Agency
FAA	Federal Aviation Administration
FANS	Future air navigation system
Fapfh	Fatal accidents per flight hour
FIR	Flight information region
FIT	FANS Interoperability Team
FL	Flight level
FMC	Flight management computer
FMS	Flight management system
GNSS	Global navigation satellite system
GOLD	Global Operational Data Link Document
HF	High frequency
HOP	Horizontal overlap probability
ICAO	International Civil Aviation Organization
IGA	International general aviation
INS	Inertial navigation system
KYA	Know Your Airspace
LDC	Lateral deviation contract
LLD	Large lateral deviation
LLE	Large longitudinal error
LOA	Letter of Agreement

MNPS	Minimum navigation performance specification
MNT	Mach number technique
NAT	North Atlantic
NM	Nautical miles
NP	Number of aircraft pairs per hour
ONP	Observed navigation performance
PARMO	Pacific Approvals Registry and Monitoring Organization
PBC	Performance-based communication
PBCS	Performance-based communication and surveillance
PBN	Performance-based navigation
PBS	Performance-based surveillance
PDC	Pre-departure clearance
PIRG	Planning and Implementation Regional Group
PORT	Pilot operational response time
PSR	Primary surveillance radar
RASG	Regional Airspace Safety Group
RASMAG	Regional Airspace Safety Monitoring Advisory Group
RCP	Required communication performance
RMA	Regional Monitoring Agency
RNAV	Area navigation
RNP	Required navigation performance
RSMP	Required surveillance monitored performance
RSP	Required surveillance performance
RVSM	Reduced vertical separation minimum
SARPs	Standards and Recommended Practices
SARSIG	Safety Analysis and Reduced Separation Implementation Group
SASP	Separation and Airspace Safety Panel
SAT	Satellite
SATCOM	Satellite communication
SATVOICE	Satellite voice
SEASMA	South East Asia Safety Monitoring Agency
SMS	Safety management system
SPG	Systems Planning Group
SSR	Secondary surveillance radar
TLS	Target level of safety
TSD	Traffic sample data
UTC	Coordinated Universal Time
VHF	Very high frequency
WATRS	Western Atlantic Route System
WPR	waypoint position report
ZNY	New York oceanic airspace

PUBLICATIONS
(referred to in this manual)

The following documents are referred to in this manual or may provide additional guidance material.

ICAO DOCUMENTS

Annexes to the Convention on International Civil Aviation

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

ATM — Air Traffic Management (PANS-ATM) (Doc 4444)

Manuals

Aircraft Type Designators (Doc 8643)

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

Location Indicators (Doc 7910)

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

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

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)

Performance-Based Communication and Surveillance (PBCS) Manual (Doc 9869)

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

Regional Supplementary Procedures (Doc 7030)

Safety Management Manual (SMM) (Doc 9859)

Global Operational Data Link (Gold) Manual (Doc 10037)

Circulars

Guidelines for the Implementation of Performance-based Longitudinal Separation Minima (Cir 343)

OTHER DOCUMENTS

Airline Coding Directory — IATA

Chapter 1

INTRODUCTION

1.1 SCOPE AND PURPOSE

1.1.1 This manual provides guidance and information to facilitate uniform application of Standards and Recommended Practices (SARPs) contained in Annex 6 — *Operation of Aircraft*, 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).

1.1.2 This manual 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 the *Performance-based Navigation (PBN) Manual* (Doc 9613) and performance-based communication and surveillance (PBCS) contained in the *Performance-Based Communication and Surveillance (PBCS) Manual* (Doc 9869).

1.1.3 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 Doc 9869.

1.1.4 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.

1.1.5 This manual 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; any organization intent upon supporting safe operations in these environments should obtain safety-assessment and monitoring guidance elsewhere.

1.1.6 The manual is organized as follows:

a) 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;

b) Chapter 3 provides specific guidance on the duties and responsibilities that support implementation of performance-based horizontal separation minima;

c) 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;

d) Appendix B provides a form for an ATS unit to provide a monthly report of large lateral deviations (LLDs) and large longitudinal errors (LLEs);

e) Appendix C provides guidance for examining LLDs and LLEs;

f) Appendix D provides the traffic sample data (TSD) to collect and use to characterize the airspace and traffic movements;

g) 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;

h) Appendix F provides an overview of collision risk modeling assumptions when assessing the application of performance-based horizontal separation minima; and

i) Appendix G and Appendix H provide sample safety assessments for the application of performance-based horizontal separation minima.

1.1.7 This manual 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 report directly to a regional safety oversight group tasked with monitoring overall system performance in light of regional safety goals. In turn, this safety oversight group will report to either the authorized Planning and Implementation Regional Group (PIRG) or the Regional Airspace Safety Group (RASG). For example, in the North Atlantic (NAT) Region, the North Atlantic Central Monitoring Agency (NAT CMA) reports to the NAT Safety Oversight Group (SOG), who is authorized by the NAT Systems Planning Group (SPG). In the Asia/Pacific (APAC) Region, several En-Route Monitoring Agencies (EMAs) report to the Asia/Pacific Regional Airspace Safety Monitoring Advisory Group (RASMAG), who reports to the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG).

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 (SMS) 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 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 manual 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 PIRG or 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 detailed in Doc 9869.

2.2 DUTIES AND RESPONSIBILITIES FOR MONITORING THE APPLICATION OF PERFORMANCE-BASED HORIZONTAL SEPARATION MINIMA

The associated duties and responsibilities are:

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

b) receive reports of large horizontal deviations identified during monitoring; 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 verify the approval status of the relevant operator;

c) proactively undertake data collections as required by the regional oversight group that oversees the safety of regional airspace to:

   1) analyse data collected on a predictive and proactive basis to detect lateral and longitudinal deviation trends and, hence, to take action as specified in 2.1.3 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) all flight operations;

      ii) operators/aircraft types; and

      iii) individual airframes;

   4) determine the appropriate method to monitor longitudinal errors;

d) archive results of performance monitoring and conduct periodic risk assessments that proactively identify aberrant changes in operational performance from agreed regional safety goals;

e) initiate necessary remedial actions and coordinate with oversight groups as necessary in the light of monitoring results;

f) monitor the level of risk as a consequence of operational errors and in-flight 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) 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) 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 2.2.

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 Member States for which they provide monitoring services for the 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 horizontal separation minima and supporting its continued safe use in order to describe the specific functions necessary to support the implementation and monitor the continued safe use of the separation minima. To ensure standardized practices where necessary, detailed guidance is elaborated further in the 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 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. annually) 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 air navigation services provider (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.

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 manual, 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 region's PIRG, 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. Such competence may be acquired through an arrangement with an organization with experience in conducting safety assessments.

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[*] All figures are located at the end of this chapter.

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, such data may not be used as the sole justification for concluding that the target level of safety (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 are 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, i.e. estimates of annual flying hours, number of flight operations, and traffic densities. The key assumptions to evaluate depend on capabilities, such as required communication performance (RCP), required surveillance performance (RSP) and required navigation performance (RNP)/area navigation (RNAV), and the specific reduced separation. For the relevant airspace, the comparative study should examine the observed system behaviour, such as the controller-pilot data link communication (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 identifying 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 Annex 11, Doc 4444, Annex 19 and the supporting guidance material contained in 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 Annex 11, Doc 4444, Doc 9869, Doc 9613 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.
Step 5	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: 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: 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 analysed 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 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	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: 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	Develop suitable safety assessment documentation, including a safety plan and associated safety cases.
Step 8	Implementation activities should include: a) trial under appropriate conditions; b) expert panel to undertake scrutiny of proposals and development of identified improvements to the implementation plan; c) development of an appropriate backup plan to enable reversion if necessary; and d) continuous reporting and monitoring results of incidents, events and observations.
Step 9	Develop suitable post-implementation monitoring and review processes.

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 operational 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 operational approvals. Monitoring organizations should publish a list of ICAO Member States for which they provide monitoring services for application of performance-based horizontal separation minima. 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, 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 operational 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, 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 Once the database described in 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 database 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. Figure 3-2 provides a flow chart depicting the process required for monitoring of operator compliance with State approvals.

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 to that shown in Appendix A, 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*

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 LLDs and LLEs.

3.4.3.2 *Monitoring core navigational performance*

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 (SSR)) 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 LLEs. Appendix F contains a description of the assumed speed variation distribution and other parameters used in the collision risk modeling.

[*] Refer to the *Guidelines for the Implementation of Performance-based Longitudinal Separation Minima* (Cir 343) for further detail on the implementation of performance-based longitudinal separation minima.

3.4.3.4 *Monitoring of LLDs and 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 minima. Accordingly, a principal monitoring function is to ensure the existence of a programme to collect this information, assess the occurrences and initiate remedial action to correct systemic problems. Guidance for initiating such remedial actions as may be necessary to resolve systemic problems uncovered by this programme is found in 3.4.4.4. One way to ensure the existence of such a programme is to develop letters of agreement (LOAs) 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 programme 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 minimum 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 programme for ATS units to provide monthly reports of LLDs and LLEs. An example of such 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) aircraft identification (or call sign) 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 the ATS unit making the 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 programme 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 programme 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 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 for establishing PBCS monitoring programmes is provided in 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 behaviour, such as:

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 such 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 APAC Region are collected by all States for the month of December each year for purposes of RVSM monitoring. During 2009, the APANPIRG expanded the usage of these 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) aircraft identification (or 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 Doc 8643;

h) origin aerodrome, as listed in Doc 7910;

i) destination aerodrome, as listed in Doc 7910;

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 determines are necessary to capture the traffic movement characteristics of the airspace.

3.4.4.1.4 Where possible, in coordinating collection of the sample, information should be provided in electronic form (i.e. 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 (ATM) 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 appears in Appendix E.

3.4.4.2.2 For some implementations of separation minima specified in 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 SMS processes that are in place within the region. Appendix F 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 found in Appendices G and H and in Doc 9689. Appendices G and H also contain sample 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; and

d) weather deviation. *Note.— these deviations may be instances where the aircraft captain initiates the manoeuvre 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 Doc 7030. For example, the generic APAC TLS is presently established, for each dimension (lateral, longitudinal and vertical), as 5×10^{-9} fatal accidents per flight hour (fapfh) 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:

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.

FIGURES FOR CHAPTER 3

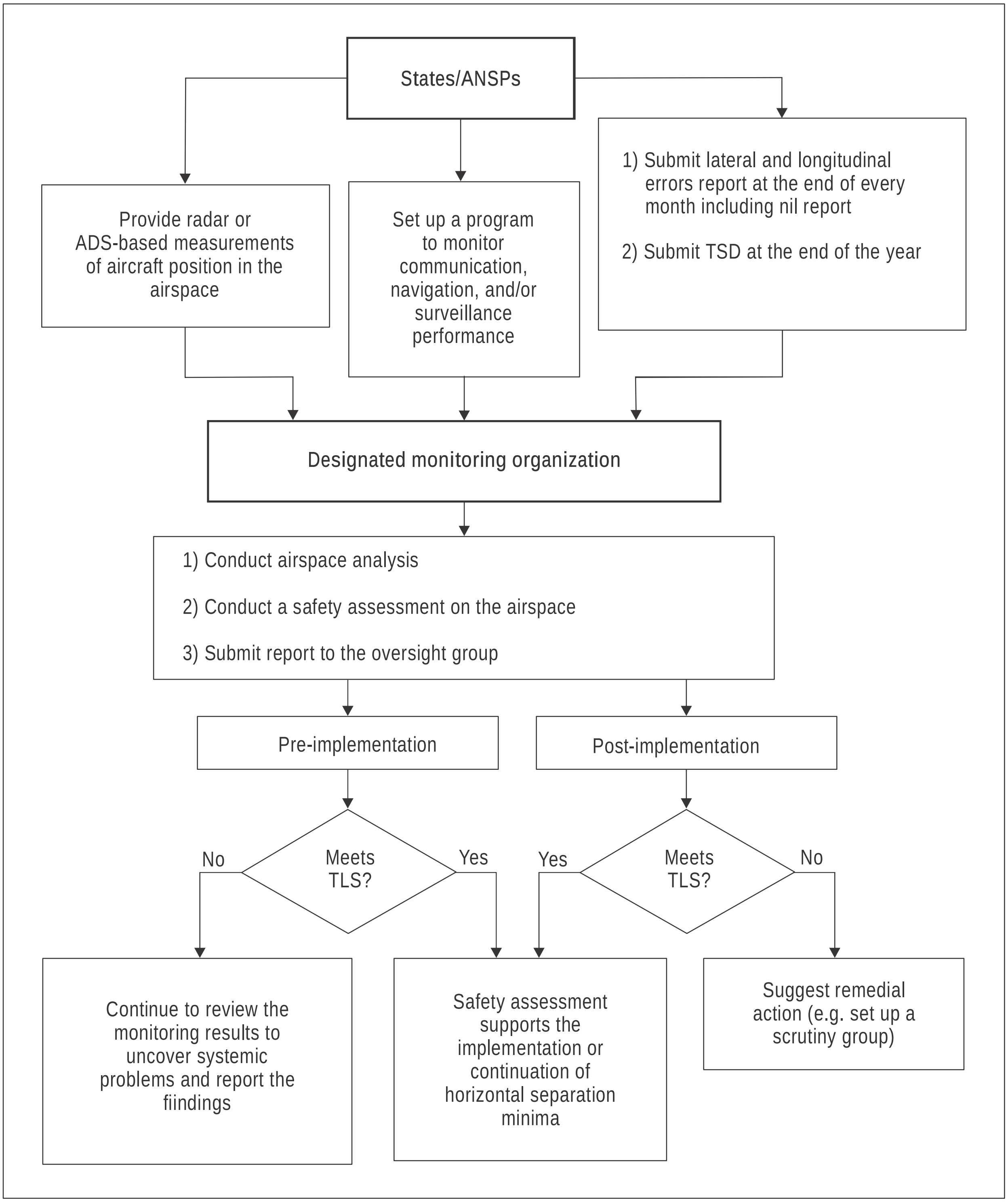

Figure 3-1. Pre/post-implementation horizontal separation minima flow chart

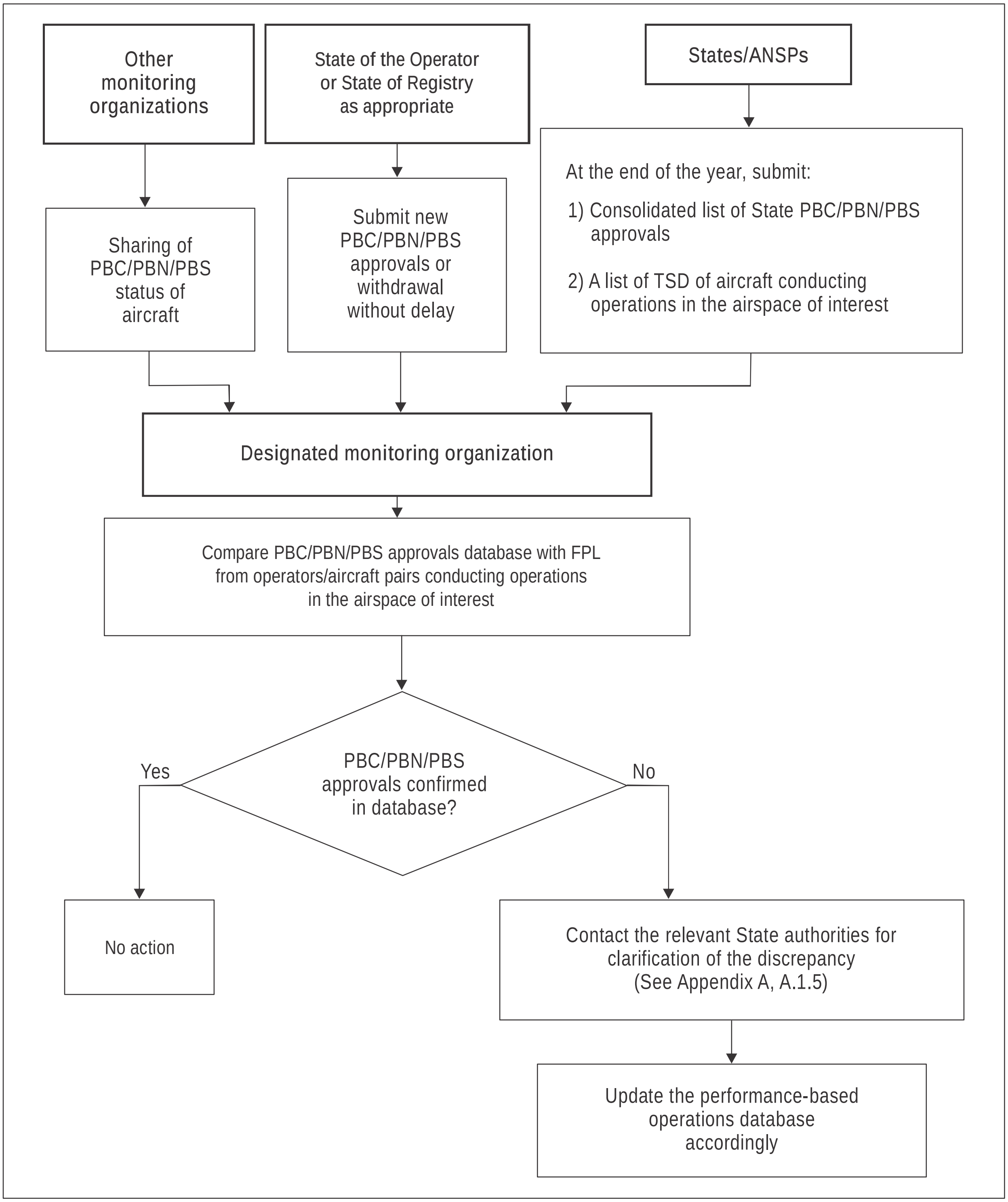

Figure 3-2. Monitoring of operator compliance with State approval requirements flow chart

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 (A.1); and

b) minimal informational content for each State performance-based operational approval to be maintained in electronic form (A.2).

A.1 FORMS FOR USE IN OBTAINING RECORDS OF PERFORMANCE-BASED OPERATIONAL APPROVALS FROM A STATE AUTHORITY

A.1.1 General

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 (A.1.2);

b) record of State performance-based operational approval (A.1.3);

c) withdrawal of State performance-based operational approval (A.1.4); and

d) letter to State authority requesting clarification of the State performance-based operational approval status of an operator (A.1.5).

A.1.1.2 The following provides guidance for completing 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 (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 A.1.3 must be completed for each operator/aircraft granted a performance-based operational approval.

c) The form provided in 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) The form provided in A.1.5 should be used to confirm the performance-based operational approval status that may be shown in a filed flight plan but not in the database of State approvals.

Note.— The fields in the forms provided in A.1.2, A.1.3 and A.1.4 should be completed as indicated in the following table.

Instructions for completing the fields in the forms under A.1.2, A.1.3 and A.1.4

Field	*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. If more than one identifier is 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.
Date of Withdrawal*	Enter date in dd/mm/yyyy format, e.g. for 26 October 2013 enter 26/10/2013.
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.
Aircraft Address (Hex)	Enter ICAO-allocated aircraft address (often referred to as Mode S or ICAO 24-bit code) in hexadecimal format.
PBC Approval Type*	Enter or select the type of PBC approval, e.g. RCP 240, RCP 400 or other. 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 other. 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 other. Enter new line for each approval type.
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 other. Enter new line for each approval type.
Remarks	Any remarks.

*where applicable

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.

A.1.2.2 Please refer to the table at A.1.1.2 for instructions on how to complete the form below. **PLEASE USE BLOCK CAPITALS**.

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 identifier 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	

Once completed, please return to the following address:

Address:

Telephone:
Fax:
Email:

A.1.3 Record of State performance-based operational 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 table at A.1.1.2 for instructions on how to complete the form below. **PLEASE USE BLOCK CAPITALS**.

State of Registry:	
State of Operator:	
Operator Identifier:	
Name of Operator:	
Operator Type:	* Civil / * Military (* delete as appropriate)
Registration Date:	
Aircraft Type:	
Aircraft Series:	
Manufacturer's Serial Number:	
Registration Mark:	
Aircraft Address (Hex):	
Number of Navigation System:	
Make/Model of Long Range Navigation System:	

PBC/PBN/PBS Approval Type:				
PBC/PBN/PBS Time Limit:				
Date of Approval:				
Date of Expiry:				
Approval Authority (CAA):				
Approving CAA Official:				
Region for PBC/PBN/PBS Approval:				
State of PBC/PBN/PBS Approval:				

Status of Previous PBC/PBN/PBS Approval: ☐ None ☐ Withdrawn

If withdrawn, please provide previous Registration Mark:

Remarks	

Once completed, please return to the following address:

Address:

Telephone:
Fax:
Email:

A.1.4 Withdrawal of State performance-based operational approval

A.1.4.1 When a State of Registry has cause to withdraw the State performance-based operational 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 table at A.1.1.2 for instructions on how to complete the form below. **PLEASE USE BLOCK CAPITALS**.

State of Registry:	
Operator Identifier:	
State of Operator:	
Aircraft Type:	
Aircraft Series:	
Manufacturer's Serial Number:	
Registration Mark:	
Aircraft Address (Hex):	

Approval Withdrawn (PBC/PBN/PBS):				
Date of Withdrawal:				
PBC/PBN/PBS Withdrawn CAA Official:				

Reason for Withdrawal:	

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

When the State performance-based operational approval status shown in the 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 (Appropriate group name, e.g. 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 its other activities, the (monitoring organization name) conducts a comparison of the State performance-based operational approval status, provided by an operator to an air traffic control unit, to the record of State performance-based operational 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 operational approval which is not confirmed by our records. The details of the occurrence are as follows:

a) Date:

b) Operator name:

c) Aircraft identification (or call sign):

d) Aircraft type:

e) Filed performance-based operational approval type:

f) ATS unit receiving notification:

4. We request that you advise this office of the State performance-based operational approval status of this operator. In the event that you have not granted a State performance-based operational 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 OPERATIONAL APPROVAL TO BE MAINTAINED IN ELECTRONIC FORM

A.2.1 Aircraft performance-based operational approvals data

To properly maintain and track performance-based operational 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 operational approval status. Table A-1* lists the minimum data fields to be collected for an individual aircraft. Table A-2 describes the approvals database record format.

A.2.2 Aircraft re-registration/operating status change data

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-3 lists the minimum data fields to be maintained to manage aircraft re-registration/operating status change data.

A.2.3 Point of contact data

An accurate and up-to-date list of contact officers is essential for the designated monitoring organization to conduct its business. Table A-4 lists the minimum content for organizational contacts and Table A-5 lists the minimum content for individual points 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 are 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 the 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-6. 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.

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* All tables are located at the end of this appendix.

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*

Performance-based operational approval data shall be exchanged among monitoring organizations. Table A-7 defines the fields required for sending a record to another monitoring organization.

A.2.4.4 *Aircraft re-registration/operating status change data*

All re-registration information as shown in Table A-8 shall be shared.

A.2.4.5 *Exchange of contact data*

All organization and individual point of contact data shall be shared in accordance with Tables A-9 and A-10.

A.2.4.6 *Confirmed non-compliant information*

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

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*

The sources of some standard data formats are as follows:

a) *Location Indicators* (Doc 7910);

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

c) *Aircraft Type Designators* (Doc 8643); and

d) *Airline Coding Directory* — IATA.

TABLES FOR APPENDIX A

Table A-1. Aircraft performance-based operational approvals data

Field	*Description*
Registration Mark	Aircraft's current registration mark.
Current Aircraft Address (Hex)	Current aircraft address (6 hexadecimal digits).
Manufacturer's Serial Number	Aircraft serial number as given by the manufacturer.
Aircraft Type	Aircraft type as defined by ICAO Doc 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 Doc 7910.
Registration Date	Date registration was active for current operator.
Operator Identifier	ICAO code for the current operator as defined in ICAO Doc 8585.
Operator Name	Name of the current operator.
State of Operator	State of the current operator as defined in ICAO Doc 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 other.
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 Doc 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.
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-2. 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
Aircraft Type	Aircraft type	Alphanumeric	4	e.g. MD11
Aircraft Mark/Series	Aircraft mark/series	Alphanumeric	6	
Serial Number	Manufacturer's serial/construction number	Alphanumeric	12	
Aircraft 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. RCP 240
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. RNP 4
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. RSP 180
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

Table A-3. Aircraft re-registration/operating status change data

Field	*Description*
Reason for Change	Example: aircraft was re-registered, destroyed, parked, etc.
Previous Registration Mark	Aircraft's previous registration mark.
Previous Aircraft Address (Hex)	Previous aircraft address (6 hexadecimal digits).
Previous Operator Name	Name of the previous aircraft operator.
Previous Operator ICAO Code	ICAO code for the 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	Name of the current aircraft operator.
New Operator ICAO Code	ICAO code for the current aircraft operator.
Aircraft ICAO Type designator	Aircraft type as defined by ICAO Doc 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 the manufacturer.
New Aircraft Address (Hex)	New aircraft address (6 hexadecimal digits).
Date Change is Effective	Date new registration/change of status became effective.

Table A-4. Organizational contact data

Field	*Description*
Type	Type of contact (e.g. operator, airworthiness authority, manufacturer).
State	State in which the company is located.
ICAO State Code	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.	Company fax number.
Telephone No.	Company telephone number.
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	Company postal code.
Country	Country in which the company is located.
Remarks	Open comments.
Modification Date	Last modification date.
Website	Company web HTTP location.
E-mail	Company e-mail address.
Civil/Military	Civil or military.

Table A-5. Individual point of contact data

Field	*Description*
Title Contact	Mr., Mrs., Ms., etc.
Surname Contact	Surname or family name of the point of contact.
Name Contact	Given name of the 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 of 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.
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 of the point of contact.
Telephone No. 2	Second telephone number of the point of contact.

Table A-6. Monitoring organization data exchange procedures

Data Type	*Data Subset*	*Frequency*	*When*
Performance-based Operational 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

Table A-7. 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 Type(s)	**Mandatory**
Date PBC Approved	**Mandatory**
Date of PBC Approval Expiry	**Mandatory**
PBN Approval Type(s)	**Mandatory**
Date PBN Approved	**Mandatory**
Date of PBN Approval Expiry	**Mandatory**
PBS Approval Type(s)	**Mandatory**
Date PBS Approved	**Mandatory**
Date of PBS Approval Expiry	**Mandatory**
Remarks	No
Date of Withdrawal of PBC/PBN/PBS Approval	**Mandatory**
Information by Authority	**Mandatory**

Table A-8. 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

Table A-9. Exchange of organizational contact data fields

Field	*Need to Share*
Type	**Mandatory**
State	**Mandatory**
ICAO State Code	Desirable
Company/Authority	**Mandatory**
Fax No.	Desirable
Telephone No.	**Mandatory**
Address (1-4)	**Mandatory**
Place	**Mandatory**
Postal Code	**Mandatory**
Country	**Mandatory**
E-mail	Desirable
Civil/Military	Desirable

Table A-10. 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

Appendix B

FORM FOR ATS UNIT MONTHLY REPORT OF LLD OR LLE

[MONITORING ORGANIZATION OR GROUP NAME]

Report of Large Lateral Deviation (LLD) or Large Longitudinal Error (LLE)

Report to the (monitoring organization 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:

Once completed, 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 the responsible officer of the Service Provider (and aircraft owner/operator if necessary)		
ATC Unit Observing Error:		
Date/Time (UTC):		
Duration of Deviation:		
Type of Error: (tick one)	☐ LATERAL	☐ 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 the 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?		☐ Yes	☐ No
Was the aircraft operating according to PBN requirements?		☐ Yes	☐ No
Was the aircraft operating according to PBS requirements?		☐ Yes	☐ No

NAVIGATION ERROR INVESTIGATION FORM

PART 3 — Detailed description of incident **(To be completed by the 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:

NAVIGATION ERROR INVESTIGATION FORM

PART 4 — To be completed by the 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 was ATC advised of the failure(s)?			

NAVIGATION ERROR INVESTIGATION FORM

PART 5 — To be completed by the investigating organization		
Have all required data been supplied?	☐ Yes	☐ No
Is further investigation warranted?	☐ Yes	☐ No
Will this incident be the subject of a separate report?	☐ Yes	☐ 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 and may 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 may be formed to discuss specific subject matters, and may 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 large lateral deviations (LLDs) and large longitudinal errors (LLEs).

C.2 PURPOSE

C.2.1 The purpose of the Scrutiny Group is to examine reports of LLDs and LLEs from the monitoring programme with the objective of determining which reports from the monitoring programme 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 analyse 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 analyse 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 minima.

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 the 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 the working group’s analysis results and take follow-up action as required.

Appendix D

TRAFFIC SAMPLE DATA (TSD) FOR TRAFFIC MOVEMENTS

This appendix describes the mandatory and optional information 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 (KYA) 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 mandatory or optional. Some of the fields listed in the table are available from the operator-filed flight plans.

Field	*Example*	*Mandatory or Optional*	*Comment*
Date (dd/mm/yyyy)	08/05/2007 for 8 May 2007	**Mandatory**	
Aircraft Call Sign	XXX704	**Mandatory**	
Aircraft Registration Mark	VH-ABC	**Mandatory**	Available in Item 18 of the operator-filed flight plan, e.g. REG/A43213
PBC Approval Type	RCP 240	**Mandatory**	Available in Item 10a of the operator-filed flight plan, e.g. P2 for CPDLC RCP 240
PBN Approval Type	RNP 4	**Mandatory**	Available in Items 10a and 18 of the operator-filed flight plan (e.g. an 'R' contained in Item 10a and RNAV specification codes contained in Item 18, e.g. PBN/A1L1
PBS Approval Type	RSP 180	**Mandatory**	Available in Item 18 of the operator-filed flight plan, e.g. SUR/RSP 180
Aircraft Type	B734	**Mandatory**	Available in the operator-filed flight plan
Origin Aerodrome	WMKK	**Mandatory**	Available in the operator-filed flight plan

Field	*Example*	*Mandatory or Optional*	*Comment*
Destination Aerodrome	RPLL	**Mandatory**	Available in the operator-filed flight plan
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	
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

SAMPLE KNOW YOUR AIRSPACE (KYA) ANALYSIS

EXAMINATION OF OPERATIONS CONDUCTED ON SOUTH CHINA SEA – RNAV ROUTES L642 AND M771

E.1 INTRODUCTION

This appendix gives an example of a Know Your Airspace (KYA) 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 the Asia/Pacific Air Navigation Planning and Implementation Group (APANPIRG) agreement, traffic movement information is collected each December from all Asia/Pacific (APAC) 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), which 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 mandatory or optional information 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 5 743 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 3-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 per cent of the operations. As will be noted, the top 4 operators account for nearly half of the operations, while the top 10 account for about 3 operations in 4.

E.3.1.3 A total of 37 unique ICAO 4-letter aircraft designators were found in the combined December 2007 TSD. Inspection of the data showed that less than one-half of one per cent 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 per cent of the December 2007 operations, are shown in Table E-2.

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 (APAC) 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 per cent 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 is 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 per cent 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 1 in 5 operations flew between Singapore Changi Airport and Hong Kong International Airport.

E.3.3 Use of the RNAV routes

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.

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* All tables are located at the end of this appendix.

E.3.4 Flight-level use on L642 and M771

Table E-5 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 per cent of the operations. The one observation at FL220 is very likely due to a minor error in data transcription or interpretation.

E.3.5 Operator/aircraft type combinations

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 per cent 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.

E.4 SUMMARY

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 the APAC Region airspace, this analysis notes the possible aircraft types and operators that might qualify for application of the horizontal separation minima.

TABLES FOR APPENDIX E

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

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

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

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

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

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

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 a required navigation performance (RNP) area navigation (RNAV) environment using an automatic dependent surveillance – contract (ADS-C) and lateral separation of aircraft on parallel or non-intersecting tracks or air traffic services (ATS) routes defined is:

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

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 Doc 9689, Appendix 1 as:

$$HOP(t\,|V_1V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2}e^{-|D_x(t)|/\lambda}\left(\frac{|D_x(t)|}{\lambda}+1\right) \qquad (2)$$

F.1.1.3 In equation (2), Dx(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 (DE) 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*.

* All tables are located at the end of this appendix.

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), future air navigation system (FANS) Interoperability Team (FIT), NAT Data Link Monitoring Agency (DLMA), or air navigation services 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 automatic dependent surveillance (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 Doc 9689, Appendix 8: 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 Tables F-2 through F-4.

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 per cent of the time (Case 3). When ADS or waypoint change event reports are received within 3 minutes, the CPDLC response will take longer than three minutes 5 per cent of the time (Case 2). It was also assumed that normal operations occur 95 per cent of the time (Case 1). The 5 per cent lateness allowance was considered to be very conservative. The weighted risk estimates based on the 3 cases is:

$$\text{weighted risk} = 0.95 \times \left(0.95 \times \text{risk}(\tau = 4) + 0.05 \times \text{risk}(\tau = 10.5)\right) + 0.05 \times \text{risk}(\tau = 13.5) \quad (3)$$

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 1.

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 system (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 cross-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 per cent 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 λv = 5.82 knots. The assumed average aircraft ground speed of 480 knots is used as the location parameter, Vo. The DE distribution is truncated at 100 knots on either side of the location parameter, 480 knots, and then normalized to equal 1.

$$f_{DE}(V) = \frac{1}{2\lambda_v} e^{-\frac{|V-V_O|}{\lambda_v}} \text{ for} - 100 < V < 100 \quad (4)$$

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 as per Doc 9689, Appendix 15 is:

$$N_{ay} = P_y(S_y)P_z(0)\frac{\lambda_x}{S_x}\left\{E_y(same)\left[\frac{\overline{|\dot{x}|}}{2\lambda_x}+\frac{\overline{|\dot{y}(S_y)|}}{2\lambda_y}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right]+E_y(opp)\left[\frac{\overline{|V|}}{\lambda_x}+\frac{\overline{|\dot{y}(S_y)|}}{2\lambda_y}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right]\right\} \quad (5)$$

F.2.1.2 The individual parameters of the lateral collision risk model and their definitions are given in Table F-5.

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 fcore(y) and ftail(y), respectively. The overall density function of the lateral deviations is modeled by the mixture f(y) = (1-α) fcore(y)+ α ftail(y), with α as the rate of atypical deviations.

F.2.2.3 The choice of a DE distribution for the distribution ftail(y) of atypical deviations and fcore(y) is considered to be conservative. The density fDE associated with a DE distribution is given by:

$$f_{DE}(y) = \frac{1}{2\lambda}e^{-\frac{|y|}{\lambda}} \text{ for } -\infty < y < \infty \quad (6)$$

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

$$f(y) = \frac{1}{2\lambda}e^{-\frac{|y|}{\lambda}} \text{ with } \lambda = -\frac{k}{\ln(0.05)} \quad (7)$$

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 per cent 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 - $\overline{|\dot{y}(S_y)|}$

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. 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(same) and E_y(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.

TABLES FOR APPENDIX F

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

Parameter	*Description*	*Units*	*Default Value*
λv	Scale parameter for the aircraft speed distribution, represents the speed decay	Knots	5.82
Vm	Maximum speed variation allowed	Knots	100
S_x	Longitudinal separation standard	NM	30, 50
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
$\overline{\lvert\dot{z}\rvert}$	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	
λz	Aircraft height	NM	
NP	Number of pairs that require controller intervention per flight hour	Per flight hour	

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

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
$\overline{\lvert \dot{z} \rvert}$	Average absolute relative vertical speed of an aircraft pair that have lost all vertical separation (e.g. vertical speed variation)	Knots	1.5
Pz(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(same)	Same direction lateral occupancy		
E_y(opp)	Opposite direction lateral occupancy		
S_x	Length of longitudinal window used to calculate occupancy	Minutes	15
$\overline{\lvert V \rvert}$	Average absolute aircraft speed	Knots	480
$\overline{\lvert \dot{y}(S_y) \rvert}$	Average absolute relative cross-track speed	Knots	
$\overline{\lvert \dot{x} \rvert}$	Average absolute relative along-track speed between aircraft on same direction routes	Knots	

Appendix G

SAMPLE 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 Region En-Route Monitoring Agency (EMA) 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 60 NM 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-pre-departure clearance (PDC)) flight levels by route and some information about routes crossing the RNAV routes.

G.2.3 The longitudinal separation minimum published for the 6 routes in November 2001 was 10 minutes with Mach number technique (MNT), or 80 NM 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.

* All tables are located at the end of this appendix.

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.

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.

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 50 NM 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 50 NM.

G.3 RESULTS OF DATA COLLECTION

G.3.1 The fidelity of large-error and traffic-count reporting by each responsible air navigation services provider (ANSP) for the period of January 2013 through December 2013 is shown in Table G-4.

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.

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

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

G.4 RISK ASSESSMENT AND SAFETY OVERSIGHT – COMPLIANCE WITH TLS VALUES

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

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

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

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

G.4.4 Tables G-8 and 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).

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.

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

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 on a trial basis, as part of the ongoing improvement to longitudinal risk assessment. The generalized model states the collision risk (Reference 1) as:

$$CR(t_0,t_1) = 2NP\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{t_0}^{t_1} HOP(t\,|V_1,V_2)P_z(h_z)\left(\frac{2V_{rel}}{\pi\lambda_{xy}}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right)f_1(V_1)f_2(V_2)\,dt\,dV_1dV_2 \qquad (3)$$

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:

$$HOP(t\,|V_1V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2}e^{-|D_x(t)|/\lambda}\left(\frac{|D_x(t)|}{\lambda}+1\right) \qquad (4)$$

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

* All figures are located at the end of this appendix.

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.

G.5.3.2 Table G-12 shows the summary of the three cases of controller's intervention buffer (τ) (References 1 and 2) used in the computation of the horizontal risk. Tables G-13, G-14 and 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:

$$0.95\times (0.95\times CR\ (\tau=4) + 0.05\times CR\ (\tau=10.5)) + 0.05\times CR\ (\tau=13.5) \quad (5)$$

G.5.3.3 In the model, the value for CPDLC uplink is stated as 90 sec (Reference 1). 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.

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

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

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.

TABLES FOR APPENDIX G

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

Table G-2. Monitored fixes in the 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

Table G-3. Reporting criteria for the South China Sea monitoring programme

Type of Error	*Category of Error*	*Criterion for Reporting*
Lateral deviation	Individual-aircraft error	15 NM 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 three minutes or more based on routine position reports
Longitudinal deviation	Aircraft-pair (time-based separation applied)	Pilot estimate varies by three 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 10 NM or more, even if separation standard is not infringed, based on ADS, radar measurement or special request for RNAV position report

Table G-4. Record of ANSP reporting by month for the period of 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
November 2013	Yes	Yes	Yes
December 2013	Yes	Yes	Yes

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 Twelve-Month Count of Traffic Reported Over Monitored Fixes Through Monitoring Month*
January 2013	9 983	11 9637
February 2013	9 666	11 9916
March 2013	10 733	12 0590
April 2013	10 711	12 1297
May 2013	11 147	12 2159
June 2013	10 744	12 2891
July 2013	10 767	12 3458
August 2013	10 824	12 4060
September 2013	10 272	12 4350
October 2013	11 139	12 5190
November 2013	10 689	12 5633
December 2013	11 484	12 6358

Table G-6. Monthly count of LLDs on South China Sea RNAV routes

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

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

Deviation Code	*Cause of Deviation*	*Number of Occurrences*
E	ATC coordination errors	4
Total		4

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 50 NM 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	50 NM	Current lateral separation minimum in South China Sea
$P_y(50)$	Probability that two aircraft assigned to parallel routes with 50 NM 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	0.0399 NM	Based on December 2013 TSD operations on L642/M771
λ_y	Aircraft wingspan	0.0350 NM	
λ_z	Aircraft height	0.0099 NM	
$P_z(0)$	Probability of vertical overlap for aircraft assigned to the same flight level	0.538	Commonly used in safety assessments
S_x	Length of half the interval, in NM, used to count proximate aircraft at adjacent fix for occupancy estimates	120 NM, 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
$\overline{V}$	Individual aircraft along-track speed	507 knots	Based on December 2013 TSD
$\overline{\lvert \dot{y}(S_y) \rvert}$	Average relative lateral speed of aircraft pair at loss of planned lateral separation of Sy	75 knots	Conservative value based on assumption of waypoint insertion error
$\lvert \dot{z} \rvert$	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 x 10^{-9} fatal accidents per flight hour	TLS adopted by APANPIRG for changes in separation minima
$P_y(0)$	Probability of lateral overlap for aircraft assigned to the same route	0.2	December 2013 TSD
$\overline{\lvert \dot{x}(m) \rvert}$	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 period	100 knots	December 2013 TSD
$\overline{\lvert \dot{y}(0) \rvert}$	Relative cross-track speed of same-route aircraft pair	1 knot	December 2013 TSD
m	Longitudinal separation minimum in NM	50 NM	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	150 NM	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 50 NM longitudinal separation minimum	December 2013 TSD

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

Table G-11. CRM parameter values

Parameters	*Description*	*Value*	*Source*
V1	Assumed average ground speed of a/c 1	480 knots	Reference 1
V2	Assumed average ground speed of a/c 2	480 knots	Reference 1
Λxy	Average aircraft wingspan or length (whichever is greater)	0.0363 NM	December 2013 TSD
Λz	Aircraft height	0.0101 NM	December 2013 TSD
Λv	scale factor for speed error distribution	5.82	Reference 1
T	ADS periodic report	27 mins	Doc 4444
NP	Number 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
$\overline{\lvert \dot{z} \rvert}$	Average relative vertical speed of a co-altitude aircraft pair assigned to the same route	1.5 knots	Commonly used in safety assessments
T	Controller intervention buffer	3 cases	Reference 1

Table G-12. Cases of τ

τ	*Minutes*
Case 1: normal ADS operations	4
Case 2: ADS report received and response to CPDLC uplink NOT received in three minutes	10.5
Case 3: ADS periodic reports takes more than three minutes	13.5

Table G-13. Case 1 normal operations

Case 1: normal ADS operations	*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 and CPDLC response not received within 3 minutes

Case 2: ADS report received and response to CPDLC uplink NOT received in 3 minutes	*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 not received

Case 3: ADS periodic reports takes more than 3 minutes	*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

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
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

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

FIGURES FOR APPENDIX G

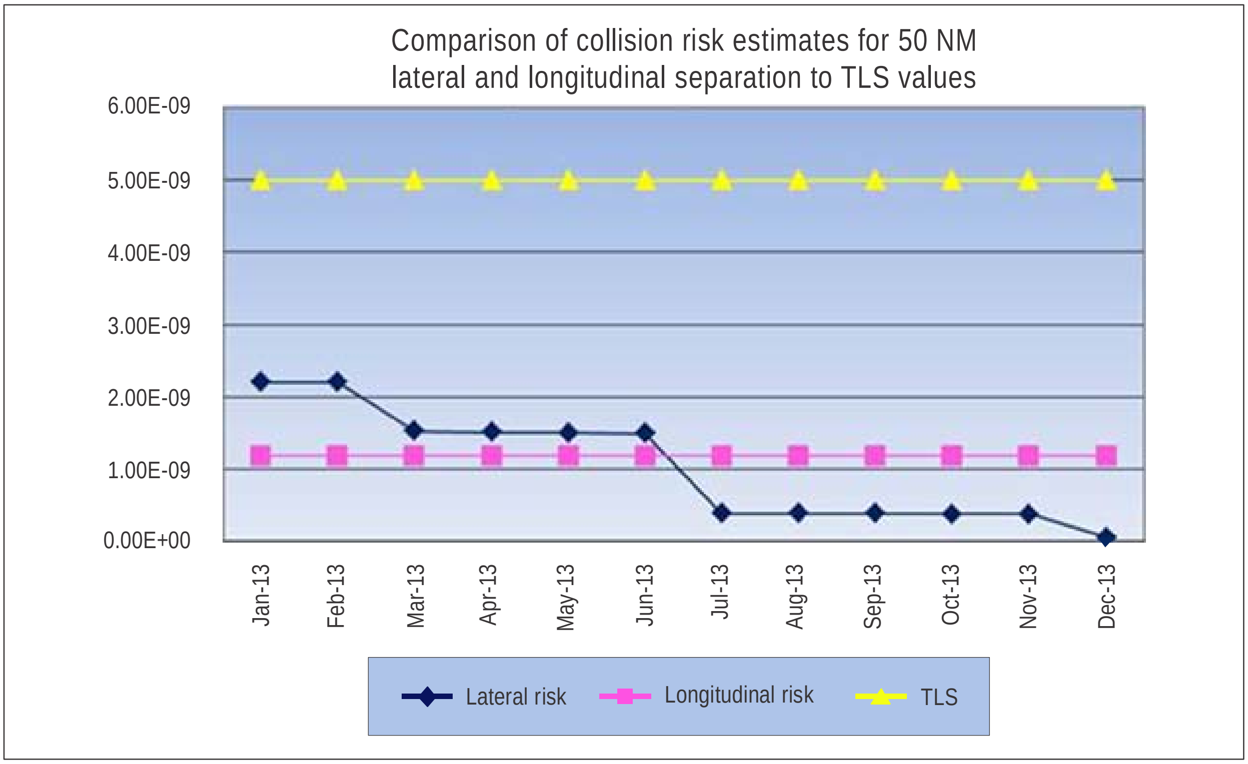

Figure G-1. Assessment of compliance with lateral and longitudinal TLS values based on navigational performance observed during the South China monitoring programme

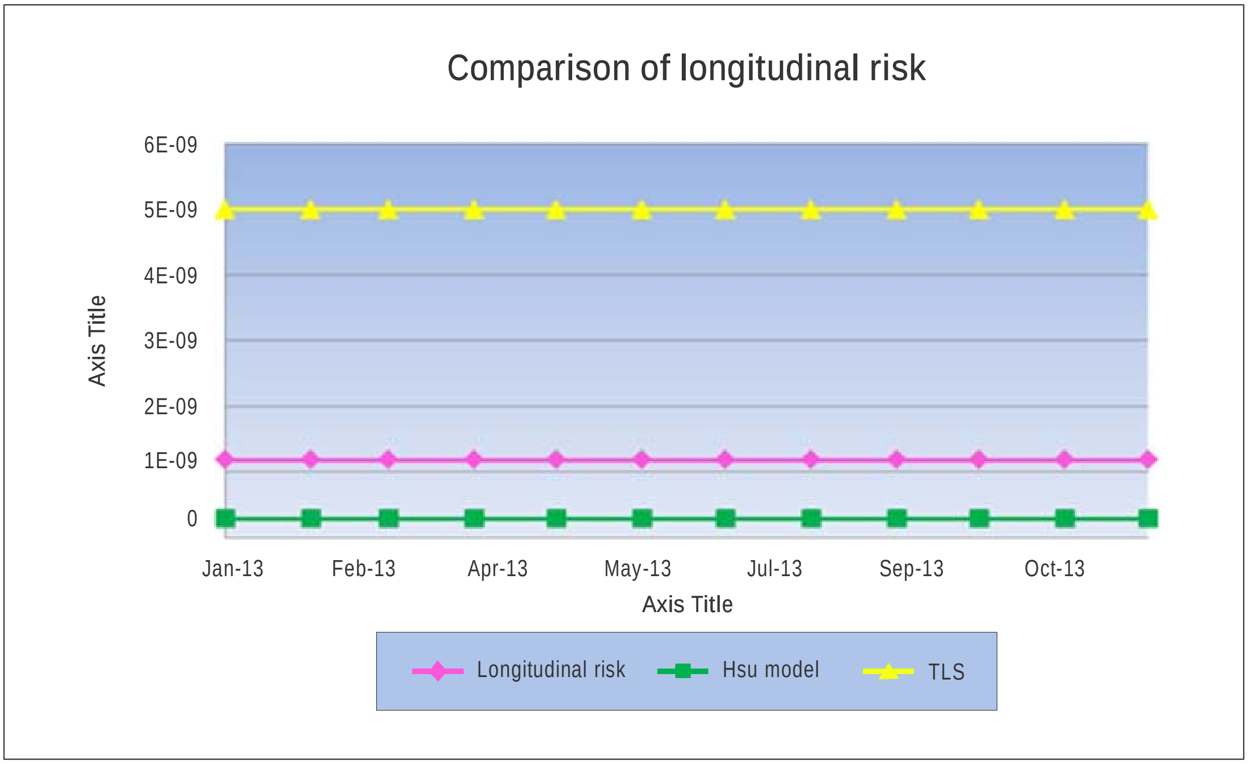

Figure G-2. Comparison of longitudinal risk values

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Appendix H

SAMPLE SAFETY ASSESSMENT — HORIZONTAL SEPARATION REDUCTION IN THE NEW YORK OCEANIC AIRSPACE

H.1. INTRODUCTION

H.1.1 The Federal Aviation Administration's (FAA) 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 air traffic control (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 the 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 30 NM 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 Docs 9689 and 9869.

H.2.2 In the New York oceanic airspace, the controller decision support system is the FAA's automated oceanic 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 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 three minutes, and six 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 Doc 4444. 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 Doc 9869.

H.2.4 As part of the safety assessment, this appendix provides verification that the ADS-C requirements contained in 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 the New York oceanic airspace. In addition, this document provides comparisons of important parameter values in the airspace of application to those of 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 THE NEW YORK OCEANIC AIRSPACE

H.3.1 Figure H-1* shows the location of the New York oceanic airspace. The western portion of the 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 the New York oceanic airspace will be referred to as a portion of the North Atlantic (NAT) airspace in this manual. The NAT airspace primarily contains operations travelling between North America and Europe. The FAA is the ATS provider for the New York oceanic FIR. The northern oceanic boundary of the 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 Navegação Aérea de Portugal.

H.3.2 An extensive analysis of operations conducted within the New York oceanic airspace is contained in the Know Your Airspace (KYA) study 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 period of September 2010 through August 2011. An estimated average of 544 flights per day operate within the 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. While high traffic volumes were observed in the WATRS portion of the New York FIR during the months of December, January, March and April, higher traffic volumes were observed in the NAT portion of the New York FIR during the months of June, July and August.

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 United States registered aircraft require a separate approval for data link operations.

* All figures are located at the end of this appendix.

H.4.2 Furthermore, 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 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).

H.4.5 Table H-1 shows that a majority of the operations in the 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 per cent, 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 per cent 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 the New York oceanic airspace. These data were collected from 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 per cent of the operations eligible for the 30 NM lateral and longitudinal separation minima. These same aircraft types, A332 and B772, represent more than 11 per cent 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 per cent 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 per cent of all operations which are eligible for the 50 NM longitudinal separation minimum.

H.5 SAFETY ASSESSMENT METHODOLOGY

H.5.1 General

H.5.1.1 In accordance with the requirements and guidance of Docs 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 the New York oceanic airspace and compares this risk to the specified TLS.

* All tables are located at the end of this appendix.

H.5.1.2 As stated in Doc 9689, the value of the TLS which applies to both the lateral and longitudinal dimensions is 5 x 10^{-9} fapfh. This is also in accordance with the NAT Systems Planning Group (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 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. Technical details of the assumptions and mathematical details of the models are found in Doc 9689.

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 (Doc 9689, Appendix 15) is:

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

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

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 found in Doc 9689, Appendix 1. Assuming that the aircraft pair are on the same identical ground track, the collision risk during a time interval [t0,t1] is given by:

$$CR(t_0,t_1) = 2NP\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\int_{t_0}^{t_1} HOP(t\,|V_1,V_2)P_z(h_z)\left(\frac{2V_{rel}}{\pi\lambda_{xy}}+\frac{\overline{|\dot{z}|}}{2\lambda_z}\right)f_1(V_1)f_2(V_2)dtdV_1dV_2 \quad (2)$$

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 (DE) distribution with known means and the same scale parameter, λ_v. The integral over V_1 and V_2 with their respective probability distributions f1(V_1) and f2(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) appears in Doc 9689, Appendix 1 as:

$$HOP(t\,|V_1V_2) = \frac{\pi\lambda_{xy}^2}{16\lambda^2}e^{-|D_x(t)|/\lambda}\left(\frac{|D_x(t)|}{\lambda}+1\right) \quad (3)$$

H.5.3.4 In equation (3), Dx(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 DE 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 per cent 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 per cent 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. Doc 9689, Appendix 1 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 below 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 Doc 4444 for ATC to revert to a larger separation (Doc 4444); and

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 the New York oceanic airspace conform to those provided in Tables H-4 through H-6, except for the CPDLC uplink time. While Doc 9689, Appendix 1 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 the New York oceanic airspace. This distribution is explained in subsequent sections of this appendix.

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

H.5.3.10 Interpretation of the parameters in Tables H-3 and 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

Several data sources are used to assist in conducting this safety assessment. These data sources provide insight into the operations of the New York oceanic airspace, and support the estimation of values for several of the parameters shown in Tables H-3 and 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 NAT Central Monitoring Agency (NAT CMA), particularly if the events occur in the minimum navigation performance specification (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 the New York MNPS airspace during the calendar interval covered by this study.

H.6.3 Ocean21 archived data

The supporting data for this safety assessment cover the one-year 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 capabilities of the Ocean21 system.

H.7 EXAMINATION OF PROXIMATE AIRCRAFT OPERATIONS IN THE NEW YORK OCEANIC AIRSPACE

H.7.1 The Ocean21 system became fully operational at the 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 of 1 June 2011 through 31 May 2012 for use in conducting the safety assessment.

H.7.2 The packing of aircraft in the 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 is examined upon entry into the airspace as well as during the operation within the airspace.

H.7.3 To examine the aircraft-packing in the New York oceanic airspace, separations between aircraft pairs are observed. Pilot/aircraft reported position times, available in the archived Ocean21 data are analysed for aircraft pairs operating within the airspace. These data were examined for the 12-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 the New York oceanic airspace is observed in terms of distance and time.

H.7.5 There were 749 aircraft pairs identified during the 12-month sample period. The aircraft in 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.

H.7.6 The data in Figure H-2 show that a small number of aircraft pairs observed with initial separations of 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.

H.7.8 The data in Figure H-3 show evidence of the application of the current 10-minute longitudinal separation minimum in the 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 travelling in the east and west direction, respectively. There were 9 and 2 aircraft pairs observed to be travelling 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 the New York oceanic airspace.

H.7.10 Of the 749 aircraft pairs identified during the period of June 2011 through May 2012, 69 aircraft pairs, or approximately 9 per cent 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 per cent 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 of 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 events is provided in Table H-8. The corresponding code definitions for horizontal-plane error reports are presented in Table H-9.

H.8.3 The events used in the lateral risk assessment are those with a lateral magnitude greater than or equal to 15 NM. There were 15 lateral events with a deviation magnitude greater than or equal to 15 NM for the collection period of June 2011 through December 2012. 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 the 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. The New York Air Route Traffic Control Center (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 of June 2011 through May 2012. Roughly 17 per cent of the LDC reports occurred during August 2011. An average of approximately 712 LDC reports is received each month.

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 the New York oceanic airspace is also shown in the figure.

H.10 WEATHER DEVIATIONS

H.10.1 Pilots are expected to follow the prescribed weather deviation procedures when weather systems are encountered within the 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 the 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 per cent of the total flight operations observed during the period. There were a total of 28 972 requests, approximately 48 per cent of which were made via CPDLC and 52 per cent 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.

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

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 the period of June 2011 through May 2012. There were 472 flights observed making weather deviation requests via both CPDLC and HF — approximately 2 per cent 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 8 per cent 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.

H.10.9 Approximately 10 255 weather deviation requests during the sample period were greater than or equal to 25 NM (half of the 50 NM lateral separation standard) — about 65 per cent of the total number of requests. Approximately 89 per cent were observed to receive a clearance and 2.1 per cent were observed to receive an *Unable* response.

H.10.10 Approximately 22 403 weather deviation requests during the sample period were greater than or equal to 15 NM (half of the 30 NM lateral separation standard) — about 77 per cent of the total number of requests. Approximately 90 per cent were observed to receive a clearance and 2.3 per cent 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 Doc 4444 address situations where the pilot cannot obtain ATC clearance, but must manoeuvre 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 per cent of the *Captain's Authority* messages were received via HF.

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 NAT 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 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 communication service providers (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 services provider (ATSP), CSP, aircraft system and aircraft operator.

H.11.2 Data link time and continuity

H.11.2.1 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 future air navigation system (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 the RCP 400 criteria when sent via HF. Similarly, the ADS-C downlink latency is required to meet the RSP 180 criteria for ADS-C downlink messages sent via satellite and VHF, and the 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 shown in Table H-12.

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 of July through 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 per cent of the transactions occurred using mixed media. The observed RCP for messages sent via HF media are not shown as only three CPDLC transactions occurred using pure HF media.

H.11.2.6 The cells colored in green highlight where the performance measures are met for observed performance in the New York FIR during the aggregate period of July through 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 per cent performance is nearly met at the *rule of thumb* between 99.0 per cent and 99.9 per cent.

H.11.2.7 The observed HF ADS-C performance does not meet the 95 per cent criteria 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 per cent and 99.9 per cent performance criteria. Figure H-9 shows the observed ADS-C latency performance over all media types for the 5 aircraft types that do not meet the 95 per cent criteria for RSP 180 during the most recent 8-month period of July 2012 through February 2013 in the New York oceanic airspace. These 5 aircraft types are B752, B753, B762, C17 and C5.

H.11.2.9 Table H-14 presents the top 33 individual airframes, in terms of the number of ADS-C reports, observed in the New York oceanic airspace from July 2012 to February 2013 that do not meet the 95 per cent criteria 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 per cent criteria) and 180 seconds (99.9 per cent criteria) are shown for each airframe in the last two columns, respectively, in Table H-14.

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 the New York oceanic airspace. In the future, once the State approval process for RCP 240 and RSP 180 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 As indicated 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.

H.11.3.2 The FAA Technical Center receives notifications of data link outages and degradations of service from the various CSPs. 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 the 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 (United States). It is not known how many flights using Iridium were affected by these degradations. However, less than one per cent of all ADS-C downlink messages and CPDLC RCP transactions sent using satellite media during the recent analysis period of February through 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 the 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 the New York oceanic airspace. The proportion of operations using the Inmarsat and Iridium systems are 98.88 and 1.12 per cent, 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 12 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 the 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 the 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 of each reported outage is maintained for 12 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.

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 conducted 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 in the period of June 2011 through May 2012.

H.11.4.2 The summary data provided in Table H-16 indicates that approximately 2.8 per cent 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). Doc 9689 conservatively assumes that an ADS report would be lost 5 per cent of the time. The longitudinal safety assessment contained in this manual also assumes a 5 per cent 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 the New York oceanic airspace. Several of these are particularly important to use for 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-colour 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 coloured 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

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 following 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 the 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.

H.13.2.1.2 As described in H.3, the New York oceanic airspace can be considered as separated into two sub-regions, WATRS and NAT. It is important to note that there are a number of published routes in WATRS, both north-south and east-west, whereas routings in the NAT portion of the New York oceanic airspace are flexible. 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.

H.13.2.2 *Probability that two aircraft assigned to the same flight level are in vertical overlap: $P_z(0)$*

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:* $\overline{|\dot{z}|}$

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 manual 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 the 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 the New York oceanic airspace over the period of 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 - $\overline{|\dot{y}(S_y)|}$

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 cross-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 the New York oceanic airspace. The assumed average aircraft speed used was 480 knots, and the typical distance between two consecutive waypoints in the New York oceanic airspace was 400 NM.

H.13.3.3 *Same and opposite direction lateral occupancies –* $E_y(same)$ *and* $E_y(opp)$

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(same) is twice the probability of longitudinal overlap, Px, for co-altitude same direction aircraft pairs on parallel routes; the same ratio multiplied by E_y(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 equation (4) as:

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

H.13.3.4.3 The DDE density is a weighted sum of two DE densities, one often called the *core* density, and the other known as the *tail* density. The weights are 1-α 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 per cent containment. The parameter λ1 representing the typical lateral errors can be estimated directly from the RNP value for the airspace. In this case, λ1 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 λ2 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 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 equation (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 the New York oceanic airspace.

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*

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 the New York oceanic airspace.

H.13.4.2 *Average aircraft wingspan or length – λxy*

The average aircraft wingspan or length, λxy, is taken to be the larger of either the average wingspan or length for the 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 – λv*

The speed error distribution is used to model variations in speed around the nominal speed. The speed error is modeled as in Doc 9689, Appendix 1 which used a scale parameter, λv 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 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 Doc 4444 for the use of the 30 NM longitudinal separation standard is 14. 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*

Tables H-4 through H-6 provide the components of the controller intervention buffer contained in Doc 9689. The safety assessment in this manual 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 the New York airspace from June 2011 through May 2012. The data in Table H-20 show that more than 99 per cent of the uplink CPDLC messages were delivered within 90 seconds.

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

H.13.4.6.1 A DE 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 per cent 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 cross-track velocities. Smaller lateral errors produce higher values of lateral overlap probability, thus increasing the risk of collision in the event that aircraft 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)*

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*

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 the New York oceanic airspace.

H.14 ESTIMATION OF LATERAL RISK AND COMPARISON TO THE TLS

Using the parameter values defined in 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 the New York oceanic airspace with a 30 NM lateral separation standard is 0.52 x 10^{-9} fapfh. This value is below the ICAO-endorsed TLS value applicable to judging the safety of the lateral separation minimum in international airspaces, 5.0 x 10^{-9} fapfh 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 H.13 and the longitudinal collision risk model stated in equation (2), the estimate of longitudinal collision risk for ADS-C aircraft operating in the 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.

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 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 eight. This means that the reporting interval must be no greater than 1 600 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 the 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 1 216 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 H.13 and the longitudinal collision risk model stated in equation (2), the estimate of longitudinal collision risk for ADS-C aircraft operating in the 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.

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. The purple line with the label 'ONP 0.3' 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 provides an acceptable estimate of collision risk for the implementation of the 30 NM longitudinal separation standard in the 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.

TABLES FOR APPENDIX H

Table H-1. Proportions of operations indicating RNP 4/RNP 10 in the filed flight plan and utilizing ADS-C in the 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	

Table H-2. Aircraft types indicating RNP 4/RNP 10 in the filed flight plan and utilizing ADS-C in the 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%
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%

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(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(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(same)	Same-direction passing longitudinal frequency
N_x(opp)	Opposite-direction longitudinal passing frequency
$\overline{V}$	Average aircraft ground speed
$\overline{\lvert\dot{x}\rvert}$	Average absolute relative along-track speed between aircraft pairs
$\overline{\lvert\dot{y}(S_y)\rvert}$	Average absolute relative cross-track speed between aircraft pairs operating on tracks nominally separated by S_y
$\overline{\lvert\dot{z}\rvert}$	Average absolute relative vertical speed between aircraft pairs

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
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

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
$[t_0,t_1]$	Time interval over which two aircraft are considered to be longitudinally separated
$D_x(t)$	Distance between the two aircraft over the time interval $[t_0,t_1]$
λ_v	Scale parameter for the speed error (about the nominal speed) distribution
T	ADS periodic report interval
T	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

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 centre to centre 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 coordination problem	
W	Weather Event – If primary code, weather deviation executed properly. If secondary code, weather was a contributing factor — deviation not executed properly	

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%

Table H-11. Observed use of *Captain's Authority* in the New York oceanic airspace – June 2011 to May 2012

CPDLC	*HF*	*Total*
89	579	668

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

Table H-13. Observed performance by data link media type in the 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	--	--	--	--	--

Table H-14. Top 33 airframes with ADS-C latency performance - the RSP 180 95 per cent criteria

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%

Operator Code	*Aircraft Type*	*Count of ADS-C Reports*	*Observed Performance at 90 seconds*	*Observed Performance at 180 seconds*
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%

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

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

Month	*Number of Operations with Overdue ADS-C Reports*	*Number of Operations Using ADS-C*	*Proportion*
Jun-11	140	4 624	3.03%
Jul-11	111	5 083	2.18%
Aug-11	94	5 392	1.74%
Sep-11	133	4 842	2.75%
Oct-11	110	5 482	2.01%
Nov-11	115	4 765	2.41%
Dec-11	189	6 015	3.14%
Jan-12	181	5 887	3.07%
Feb-12	245	5 068	4.83%
Mar-12	200	5 550	3.60%
Apr-12	165	5 635	2.93%
May-12	132	5 449	2.42%
Average	151.25	5 316	2.84%

Table H-17. Weighted size of the aircraft eligible for the reduced separation standards in the New York oceanic airspace

Aircraft Type	*Proportion*	*Length (NM) λx*	*Wingspan (NM) λy*	*Height (NM) λz*
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
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

Table H-18. Weighted aircraft size of operations eligible for the reduced separation standards in the New York oceanic airspace - WATRS and NAT Regions

Airspace	*Length (NM) λx*	*Wingspan (NM) λy*	*Height (NM) λz*
New York oceanic (ZNY)	0.03087	0.02826	0.00876
WATRS	0.02760	0.02507	0.00808
NAT	0.03402	0.03117	0.00939

Table H-19. Parameter values for the lateral collision risk model for the 30 NM lateral separation standard in the New York oceanic airspace

Parameter Symbol	*Parameter Definition*	*Parameter Value*	*Source for Value*
$\overline{\lvert \dot{x} \rvert}$	Average absolute relative along-track speed between aircraft on same direction routes	27 knots	Estimated from ADS-C reports in traffic sample
$\overline{\lvert V \rvert}$	Average absolute aircraft air speed	480 knots	
$\overline{\lvert \dot{y}(30) \rvert}$	Average absolute relative cross-track speed	36 knots	
$\overline{\lvert \dot{z} \rvert}$	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 wingspan	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	
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(same)	Same direction lateral occupancy	0.0641	Average value estimated from traffic movement sample
E_y(opp)	Opposite direction lateral occupancy	0.0005	Average value estimated from traffic movement sample

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≤X<30	68 084	95.86%	95.86%
30≤X<60	1 760	2.48%	98.34%
60≤X<90	838	1.18%	99.52%
90≤X<120	228	0.32%	99.84%
120≤X<150	63	0.09%	99.93%
150≤X<180	29	0.04%	99.97%
X≥180	22	0.03%	100.00%
Total	71 024		

Table H-21. Longitudinal collision risk parameters for the 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	
λxy	Average aircraft wingspan or length	0.0308 NM	Estimated from the New York traffic sample data
λv	Scale parameter for speed error distribution	5.82 knots	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	Three cases (see Tables H-4 through H-6) with empirical data for ZNY CPDLC uplink in Table H-20	Doc 9689, Appendix 1
NP	Number of aircraft pairs per hour	1	Conservative estimate

FIGURES FOR APPENDIX H

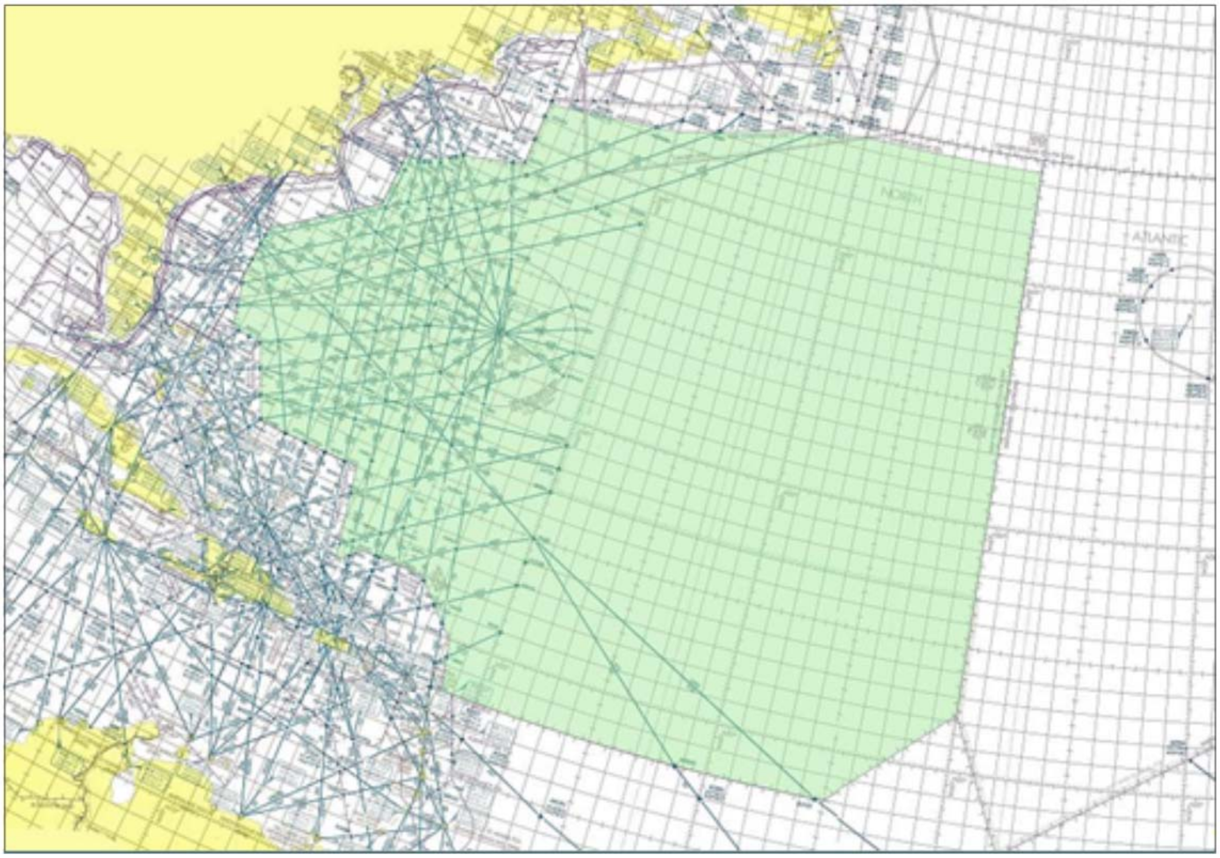


Figure H-1. New York oceanic airspace

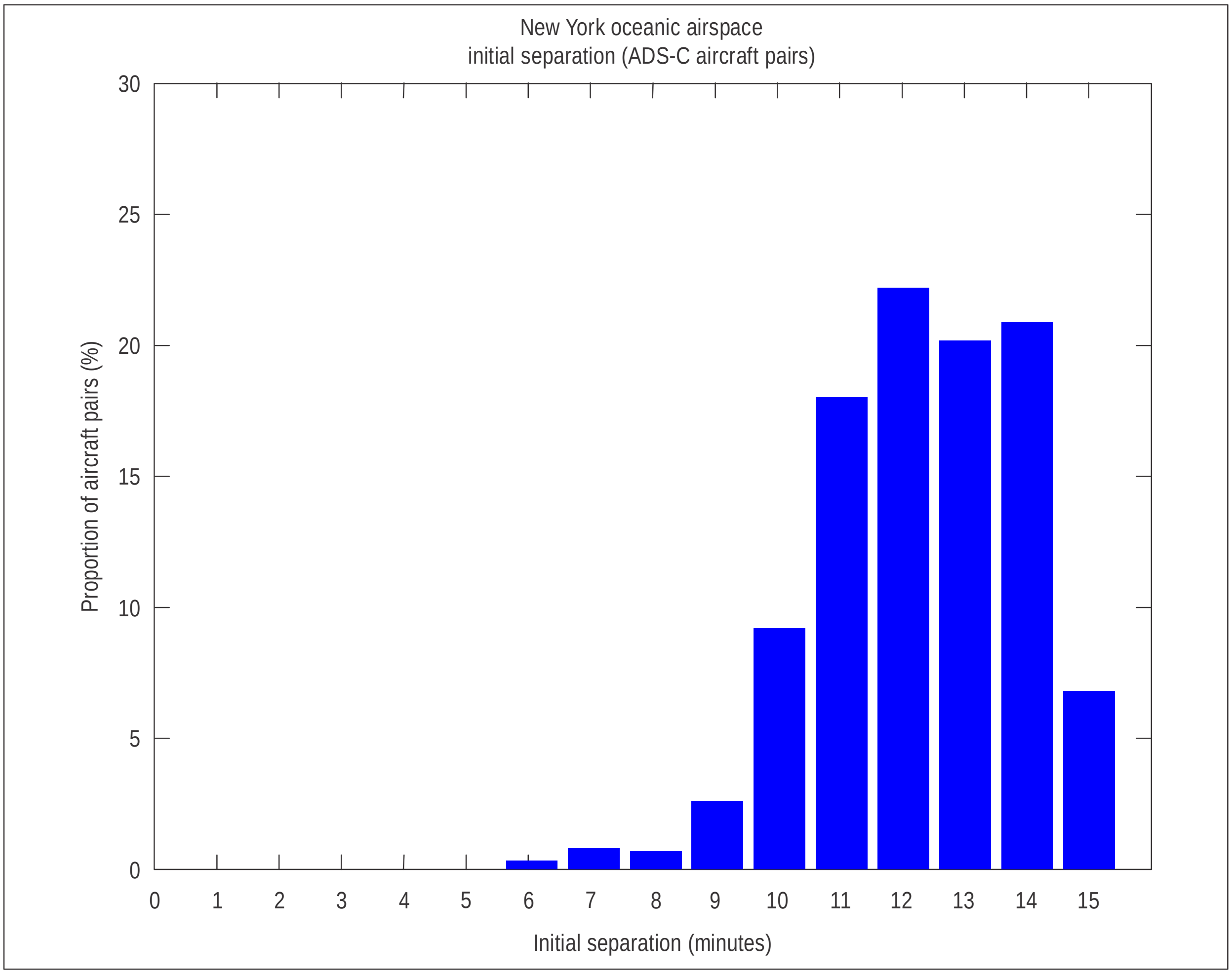


Figure H-2. Initial separation (time) between longitudinally proximate ADS-C operations within the New York oceanic airspace – June 2001 through May 2012

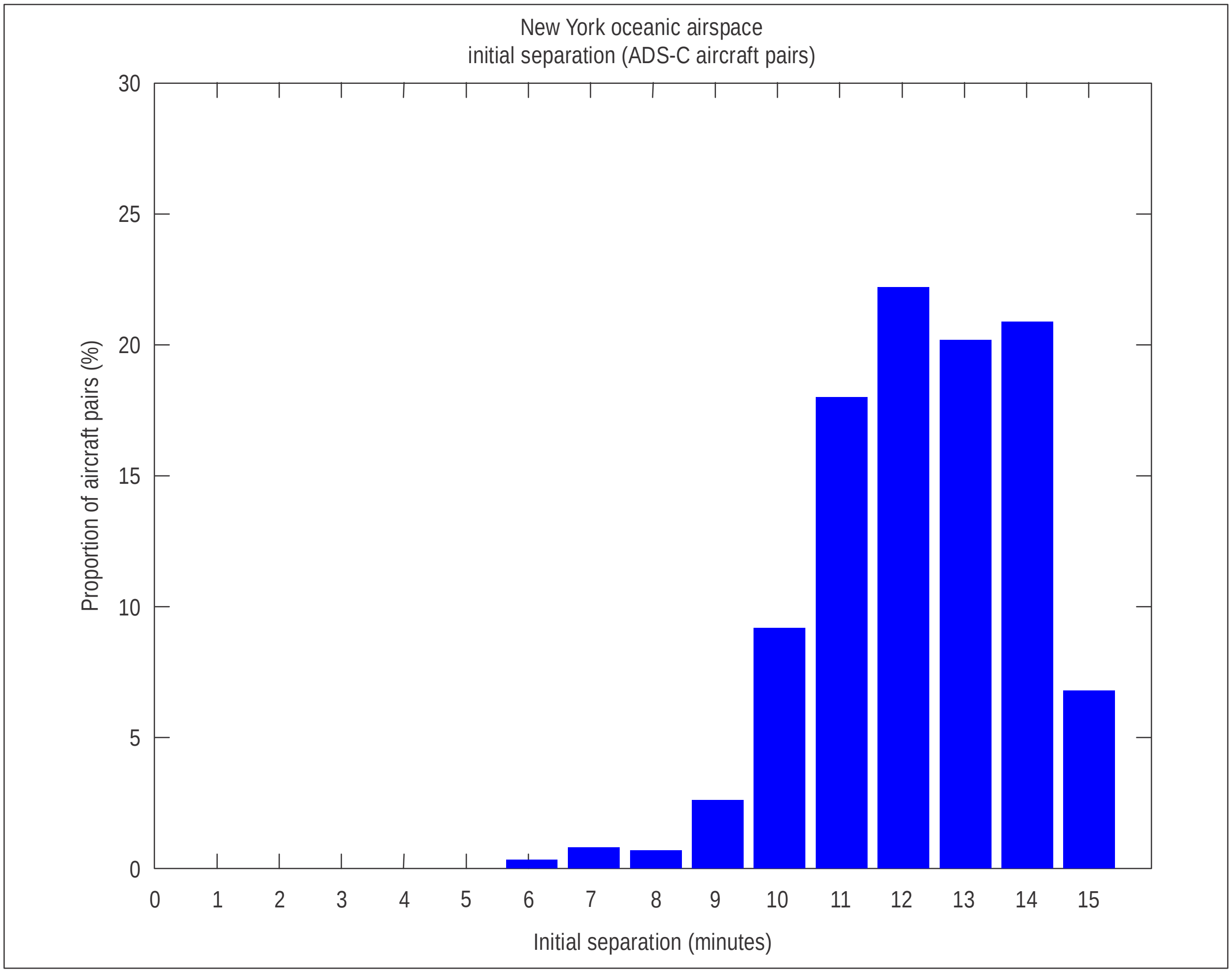
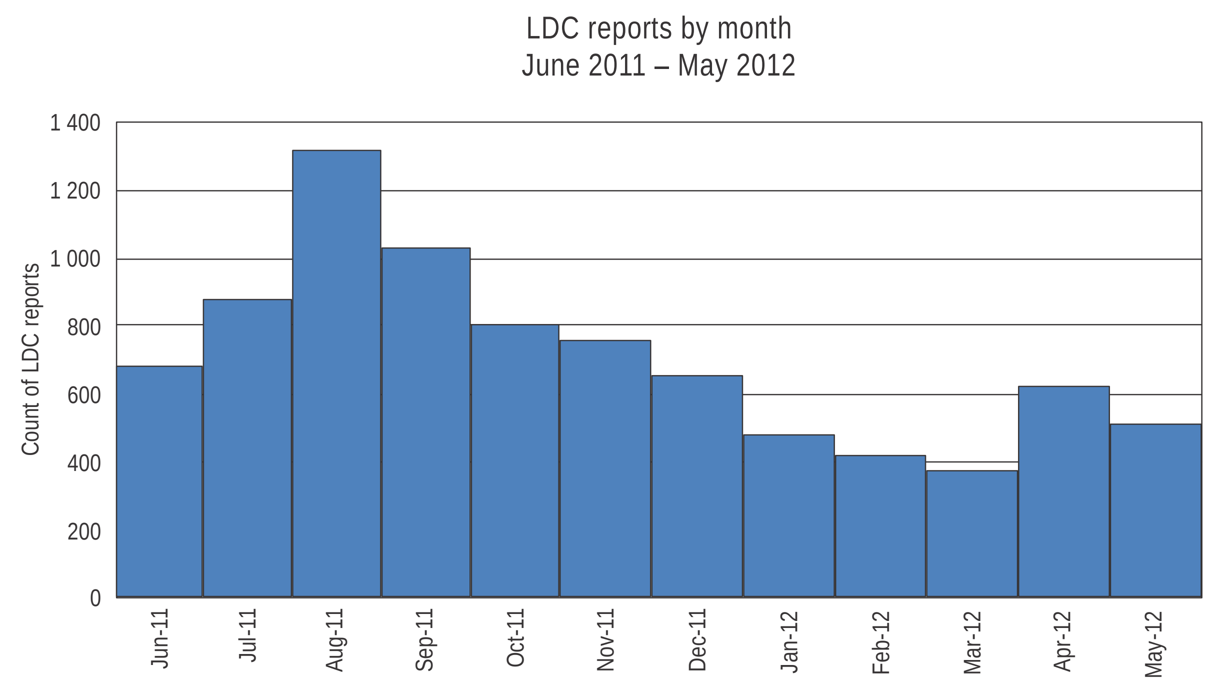


Figure H-3. Initial separation (distance) between longitudinally proximate ADS-C operations within the New York oceanic airspace – June 2001 through May 2012



	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-11	Jan-12	Feb-12	Mar-12	Apr-12	May-12
LDC	678	868	1 329	1 030	803	758	651	475	417	371	619	509

Figure H-4. Count of LDC reports per month – June 2011 through May 2012

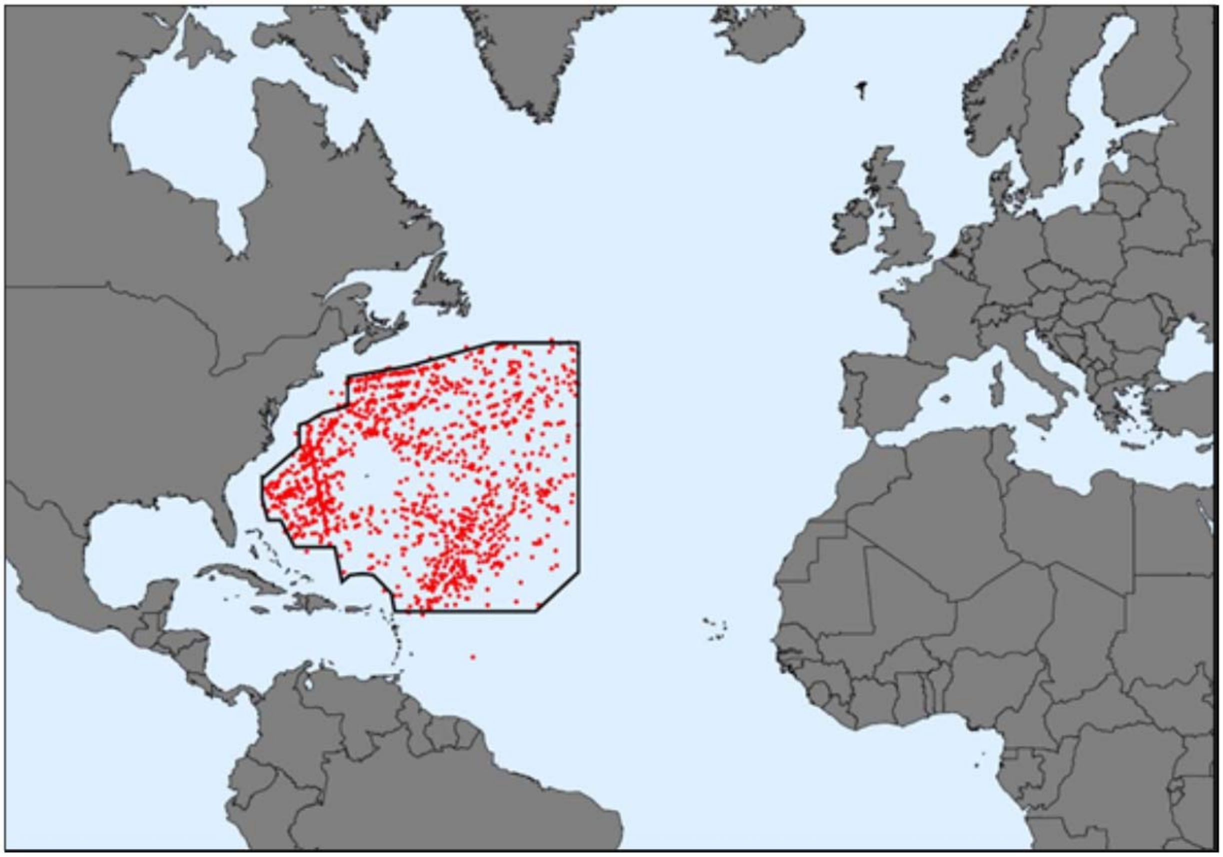


Figure H-5. Locations of received LDC event reports for August 2011

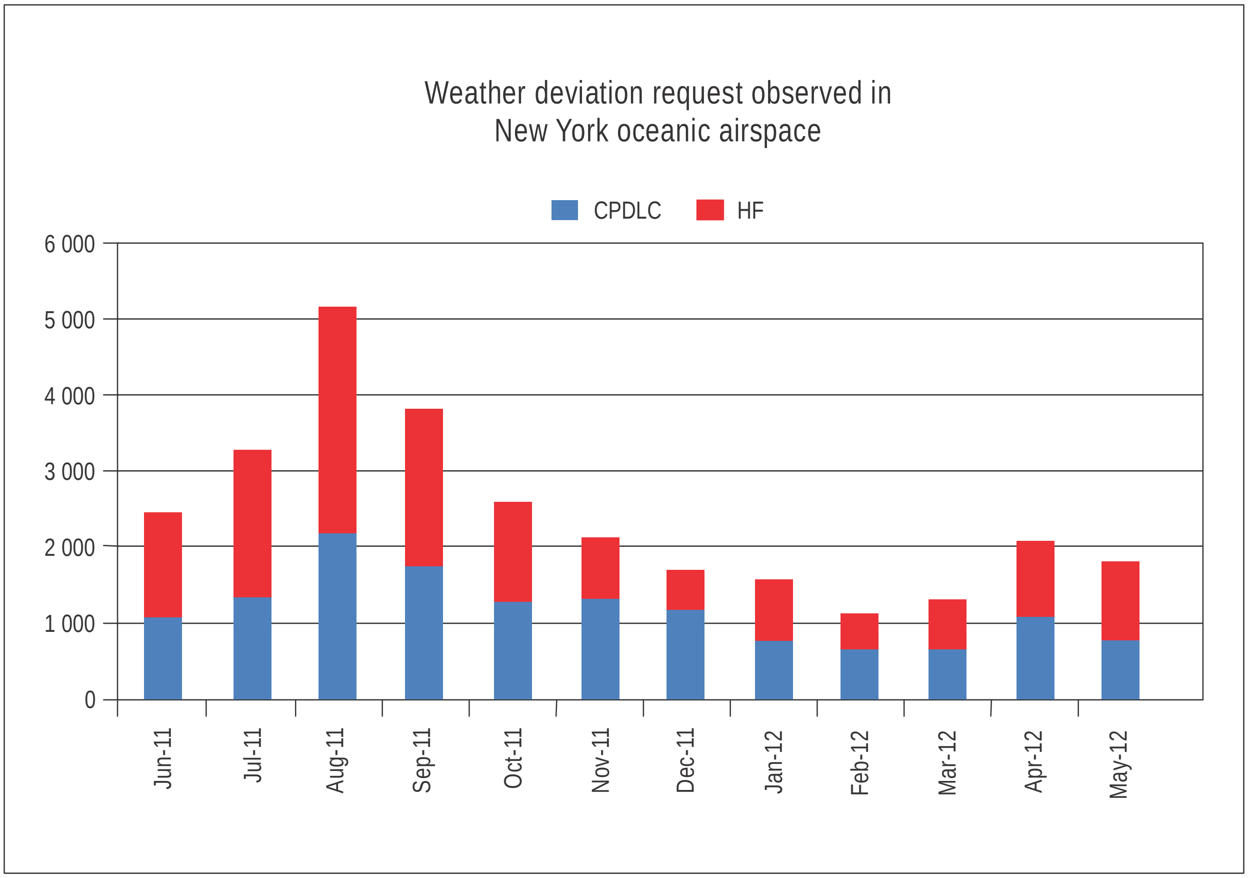


Figure H-6. Weather deviation requests observed in the New York oceanic airspace by month

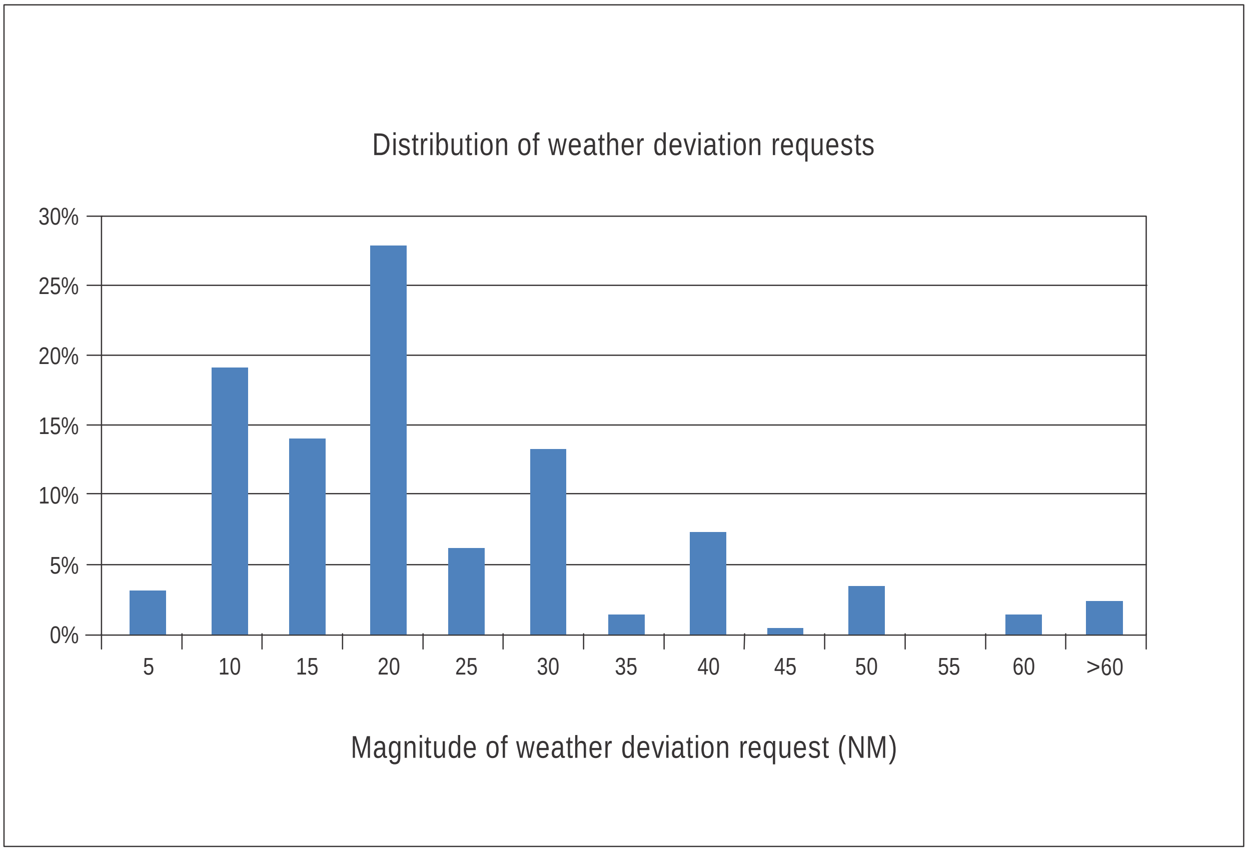


Figure H-7. Distribution of weather deviation requests – magnitude (NM)

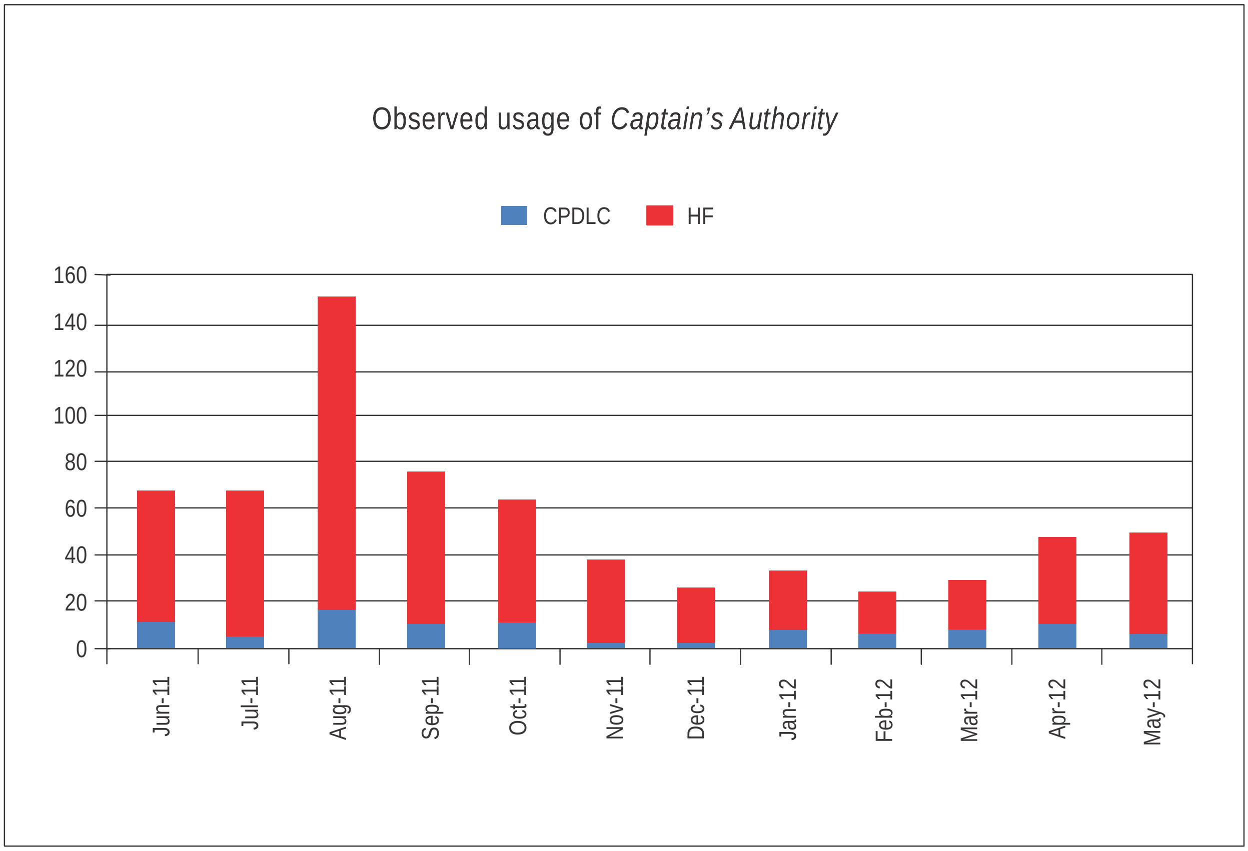


Figure H-8. Observed usage of *Captain's Authority* in the New York oceanic airspace by month

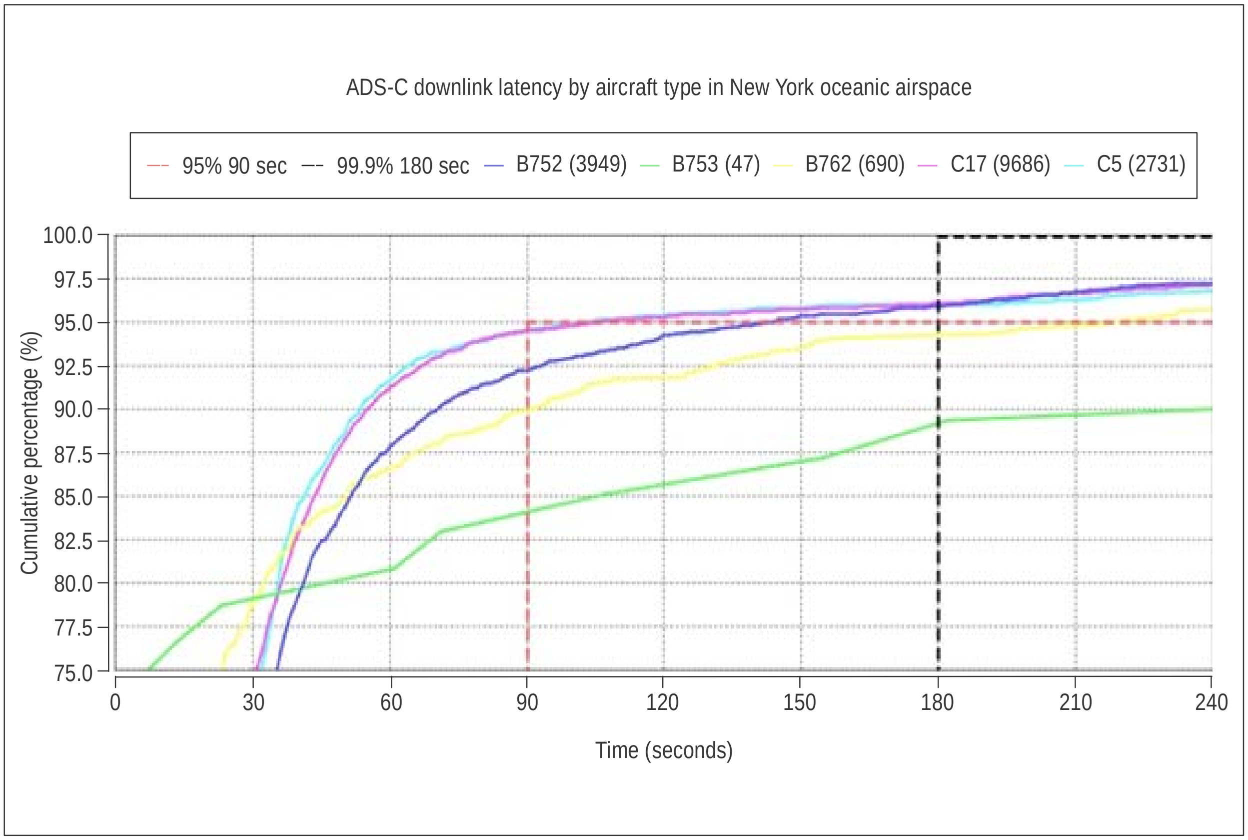


Figure H-9. ADS-C downlink latency performance for aircraft types with observed performance below 95 per cent criteria – July 2012 through February 2013

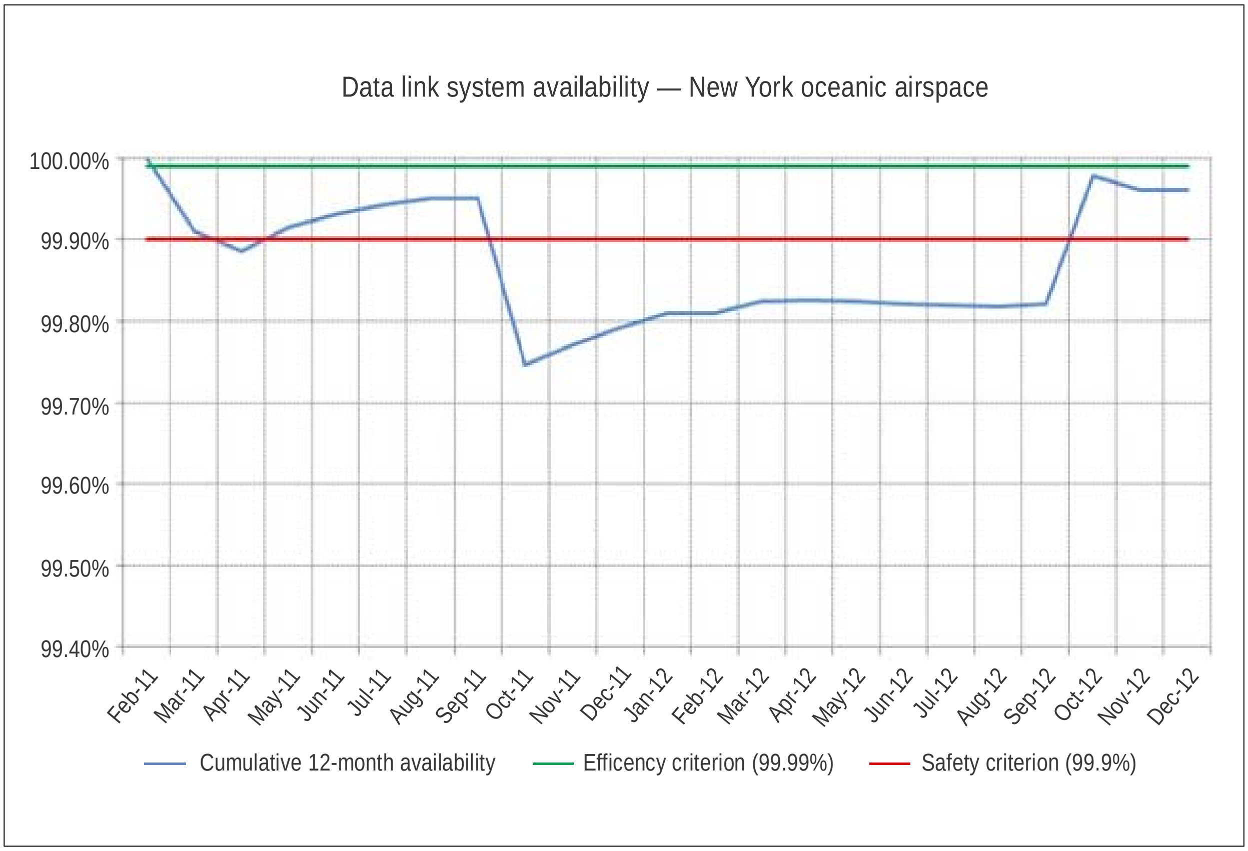


Figure H-10. Data link system availability – New York oceanic airspace

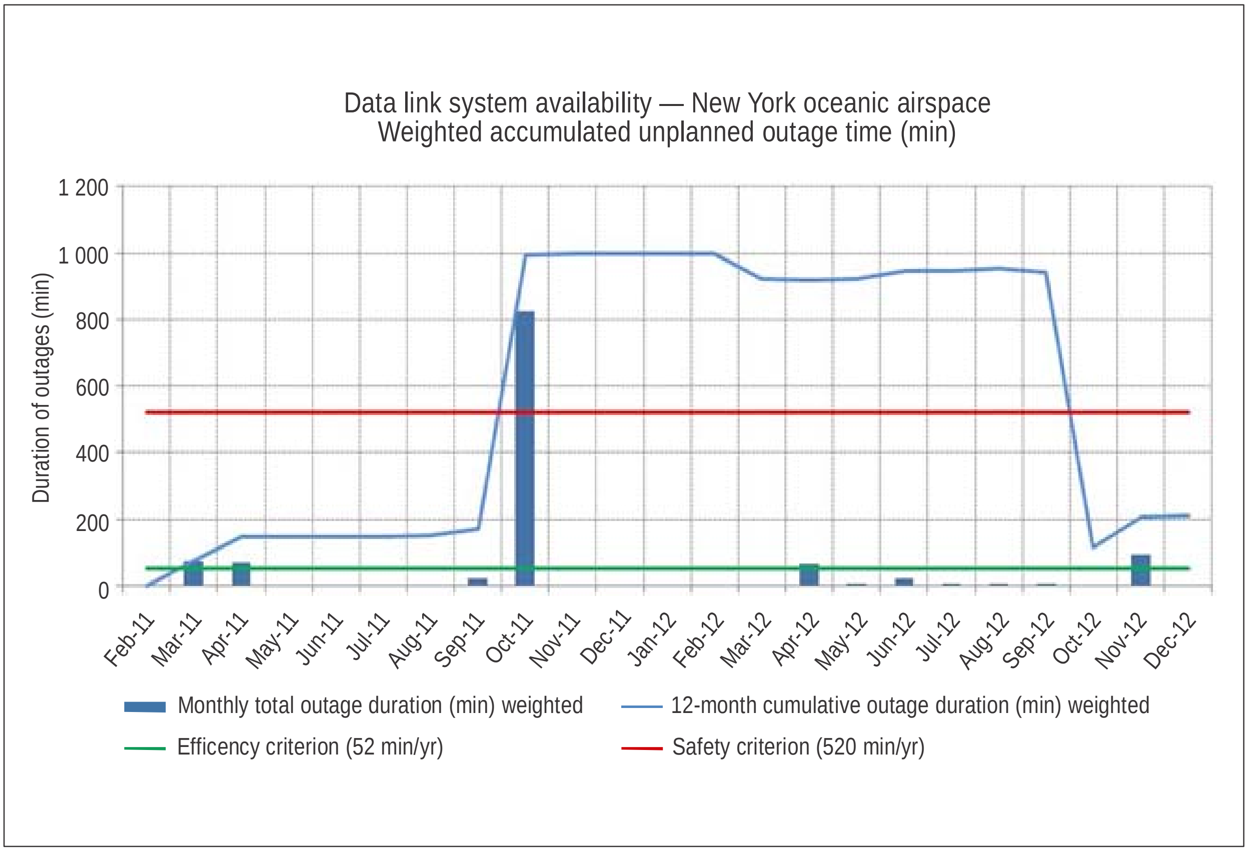


Figure H-11. Data link system availability – weighted accumulated unplanned outage time (minutes)

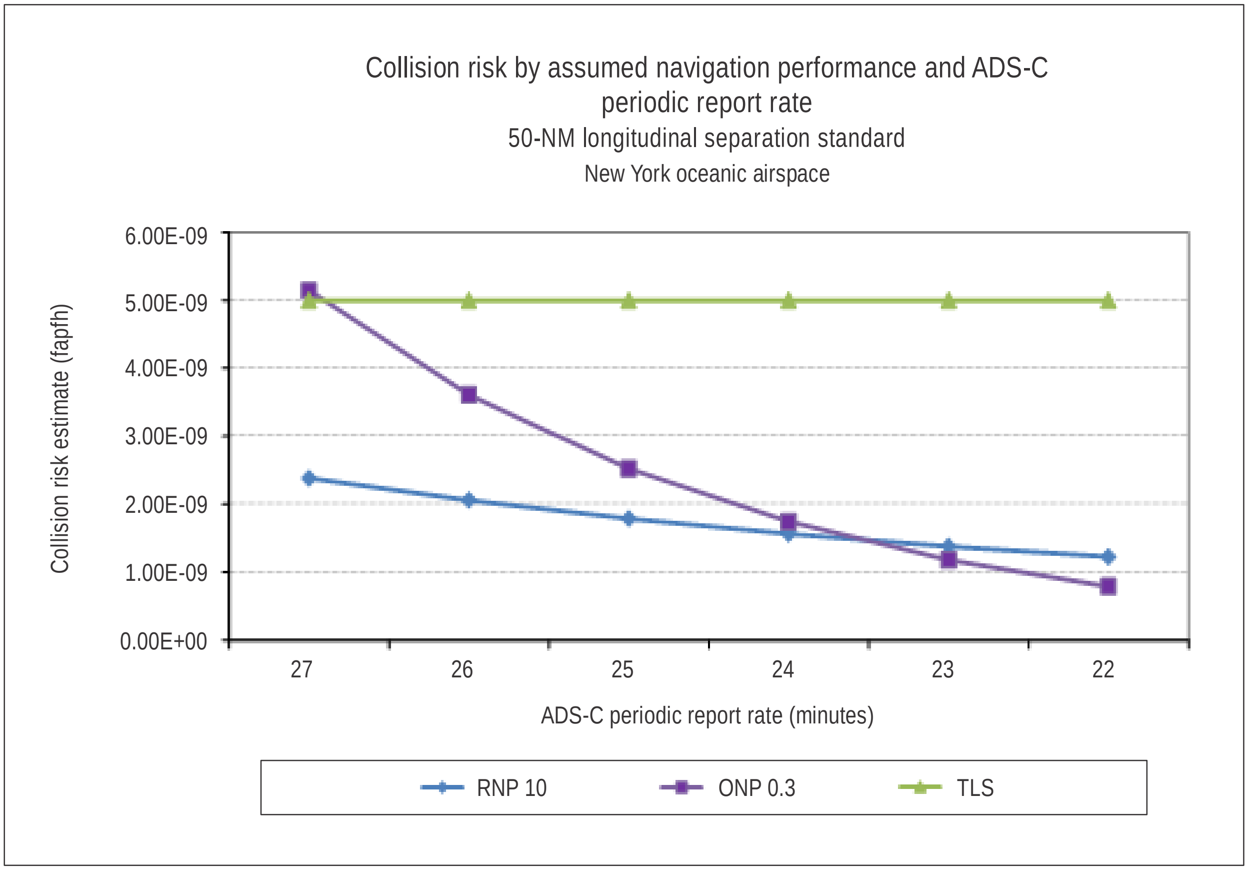


Figure H-12. Longitudinal collision risk by ADS-C report rate and assumed navigation performance – 50 NM longitudinal separation minimum

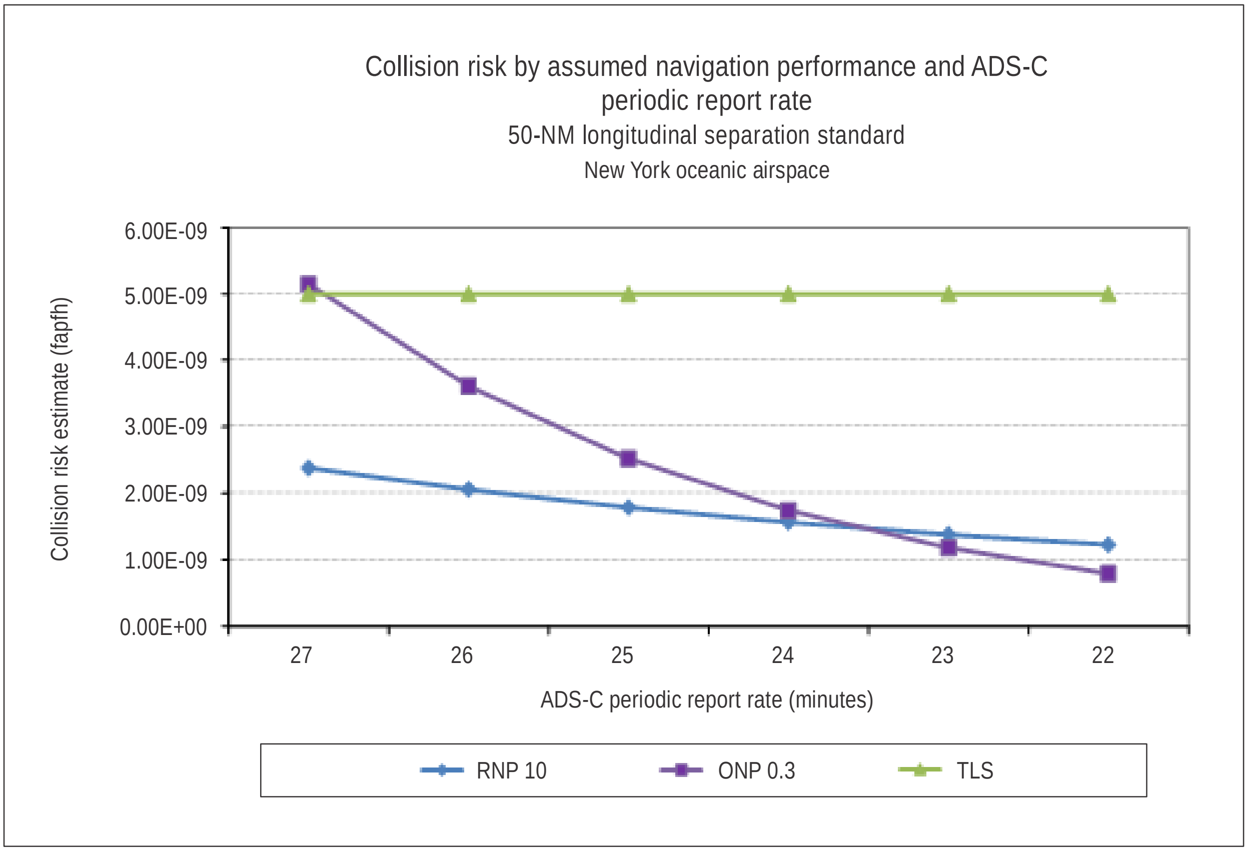


Figure H-13. Longitudinal collision risk by ADS-C report rate and assumed navigation performance – 30 NM longitudinal separation minimum

— END —

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