International Civil Aviation Organization

The Sixteenth Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/16)

Bangkok, Thailand, 20 – 24 February 2012

Agenda Item 5: Airspace Safety Monitoring Activities/Requirements in the Asia/Pacific Region

SAFETY ASSESSMENT TO SUPPORT USE OF THE 30-NM LATERAL AND 30-NM LONGITUDINAL SEPARATION STANDARDS IN ANCHORAGE OCEANIC AND OFFSHORE AIRSPACE

(Presented by the United States of America/ Pacific Approvals Registry and Monitoring Organization (PARMO))

SUMMARY

This paper presents the safety assessment for the implementation of the 30-NM lateral and 30-NM longitudinal separation standards in Anchorage Oceanic and Offshore Airspace. This document provides a summary of the airspace characteristics and the related observed data link performance. The estimate of lateral and collision risk satisfies the target level of safety (TLS) value applicable to judging the safety of the lateral separation standards, 5.0 x 10^{-9} fatal accidents per flight hour due to the loss of planned lateral separation. The estimate of longitudinal collision risk for the implementation of the 30-NM longitudinal separation standard for RNP 4 operations using ADS-C with a reporting rate of 10-minutes within Anchorage Oceanic and Offshore Airspace satisfies the applicable TLS value. This document describes the related planned post-implementation monitoring activities.

This paper relates to –

Strategic Objectives:

*A: **Safety** – Enhance global civil aviation safety*

Global Plan Initiatives:

GPI-9 Situational awareness
GPI-16 Decision support systems and alerting systems
GPI-21 Navigation systems
GPI-22 Communication infrastructure

1. INTRODUCTION

1.1 The Pacific Approvals Registry and Monitoring Organization (PARMO), a service provided by the U.S. Federal Aviation Administration's Technical Center, recently conducted a safety assessment for the implementation of the 30-NM lateral and 30-NM longitudinal separation standards in Anchorage Oceanic and Offshore Airspace. This safety assessment is contained in this paper as Attachment A.

2. DISCUSSION

2.1 This paper contains the PARMO safety assessment for the introduction of the 30-NM lateral and 30-NM longitudinal separation standards in Anchorage Oceanic and Offshore Airspace. It contains a summary of airspace characteristics, related data link performance, reported horizontal errors, and collision risk methodology.

3. ACTION BY THE MEETING

3.1 The meeting is invited to

a) note the results of the airspace safety assessment presented in this paper, and

b) discuss any relevant matters as appropriate.

Safety Assessment to Support Use of the 30-NM Lateral and 30-NM Longitudinal Separation Standards in Anchorage Oceanic and Offshore Airspace

FAA Technical Center
Atlantic City NJ

Version 1.1
January 2012

Executive Summary

This document contains the safety assessment for the implementation of the 30-NM lateral and 30-NM longitudinal separation standards in Anchorage Oceanic and Offshore Airspace. The requirements for implementation of 30-NM lateral and 30-NM longitudinal separation standards using automatic dependent surveillance (ADS) are listed in the International Civil Aviation Organization's (ICAO's) Document 4444, Procedures for Air Navigation Services ATM/501. Among them are that aircraft be approved to Required Navigation Performance (RNP) 4 and have direct controller-pilot communications (DCPC). The ADS service must operate with a maximum periodic reporting interval no greater than 14 minutes. The safety assessment presented in this document includes information verifying that the ADS requirements of ICAO Document 4444, as they pertain to application of the 30-NM lateral and 30-NM longitudinal separation standards, are satisfied in Anchorage Oceanic and Offshore Airspace.

The Ocean21 automation system became fully operational on 1 March 2007 in Anchorage Oceanic and Offshore Airspace. Data collected from the Ocean21 system for the period September 2010 through August 2011 were used in this safety assessment. Analyses of these data show an average of 440 flights per day operate within Anchorage Airspace, an average of 152 flights per day operate within the oceanic portion of Anchorage Oceanic and Offshore Airspace. Seventy-five percent, or 115 flights per day, utilize ADS for position reporting.

This document provides a summary of data link performance for operations conducted within Anchorage Oceanic and Offshore Airspace. It also provides a description of the lateral and longitudinal collision risk models and presents the parameter estimates used in the safety assessment.

The estimate of lateral collision risk for the implementation of the 30-NM lateral separation standard is 3.35×10^{-9} fatal accidents per flight hour for RNP 4 operations using ADS-C within Anchorage Oceanic and Offshore Airspace. This value satisfies the target level of safety (TLS) value applicable to judging the safety of the lateral separation standard, 5.0×10^{-9} fatal accidents per flight hour due to the loss of planned lateral separation.

The estimate of longitudinal collision risk for the implementation of the 30-NM longitudinal separation standard is 2.92×10^{-9} fatal accidents per flight hour for RNP 4 operations using ADS-C with a reporting rate of 10-minutes within Anchorage Oceanic and Offshore Airspace. This value satisfies the TLS value applicable to judging the safety of the longitudinal separation standard, 5.0×10^{-9} fatal accidents per flight hour due to the loss of planned longitudinal separation.

This document also describes the planned post-implementation monitoring activities related to the implementation of the 30-NM lateral and 30-NM longitudinal separation minima in Anchorage Oceanic and Offshore Airspace to be conducted by the FAA Technical Center. The results of these activities will be provided in the horizontal safety monitoring report submitted to the ICAO Asia and Pacific Regional Airspace Safety Monitoring Advisory Group (RASMAG) twice a year. Amongst other safety-related information, the horizontal safety monitoring report includes a current estimate of the lateral and longitudinal collision risk based on the most recent reported events and traffic data.

1. Introduction

1.1. In October 2005, the U.S. Federal Aviation Administration (FAA) introduced the Ocean21 oceanic automation system into full time operation at the Oakland Air Route Traffic Control Center (ARTCC) (ZAK). The Ocean21 system was developed by the FAA under the Advanced Technologies and Oceanic Procedures (ATOP) program. The Ocean21 system features a fully integrated conflict probe, data link communications, and automatic processing of mixed mode position reporting such as radar, high frequency radio, DataComm, and automatic dependent surveillance.

1.2. In November 2005, the FAA implemented the 50-NM longitudinal separation standard in the Oakland Oceanic Flight Information Region (FIR). This implementation was made possible with the introduction of the Ocean21 system and improvements made in the communication, navigation, and surveillance (CNS) systems by the airspace users and service providers. The 50-NM longitudinal separation standard is available between pairs of suitably equipped aircraft in the Oakland FIR.

1.3. In December 2005, the FAA introduced the 30-NM lateral and 30-NM longitudinal separation standards into the Oakland FIR as an operational-trial. The reduced horizontal separation minima are available for suitably equipped RNP 4 aircraft conducting operations in the Oakland FIR. The application of the reduced horizontal separation standards is accomplished ad hoc between pairs of suitably equipped aircraft; this means that the application of the separation minima is not planned prior to oceanic entry.

1.4. In March 2007, the FAA introduced the Ocean21 oceanic automation system into full-time operation in oceanic sectors 10 and 11 in Anchorage Oceanic and Offshore Airspace. In November 2008, the FAA introduced the 50-NM longitudinal separation minimum in Anchorage Oceanic and Offshore Airspace for suitably equipped RNP 10 operations. In November 2010, the FAA introduced the 50-NM lateral separation standard into Anchorage arctic oceanic airspace for RNP 10 operations.

1.5. The FAA plans to introduce the 30-NM lateral and 30-NM longitudinal separation standards in Anchorage Oceanic and Offshore Airspace in 2012. The purpose of this document is to present background information and the safety assessment for the application of the 30-NM lateral and 30-NM longitudinal separation minima in Anchorage Oceanic and Offshore Airspace.

2. Safety Assessment Background

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 30-NM lateral and longitudinal separation minima. These risk estimates will be compared to the Target Level of Safety (TLS) of 5×10^{-9} fatal accidents per flight hour (fapfh) due, separately, to the loss of 30-NM lateral and 30-NM longitudinal separation, following the guidelines for implementing these separation minima in international airspace and formerly contained within ICAO Annex 11.

2.2. In Anchorage Oceanic and Offshore Airspace, the controller decision support system is the FAA's automated oceanic air traffic control (ATC) system, Ocean21. The decision support system is used to project a conflict-free path for an aircraft between it and others with applicable separation minima. The Ocean21 system is fully compliant with the requirements formerly contained within Annex 11 Attachment B and currently contained within ICAO Doc 4444 (reference 1) regarding the application of automatic dependent surveillance (ADS-C) and controller-pilot data link communications (CPDLC) in support of 30-NM lateral and longitudinal separation standards, such as:

2.2.1. Establishing ADS-C contracts with an appropriate periodic update rate for suitably approved aircraft;

2.2.2. Establishing a lateral deviation event contract set to 5-NM; and

2.2.3. Reversion to an alternate procedural separation if ADS-C message is overdue by 3 minutes and 6 minutes have elapsed since controller began attempting to establish communication.

2.3. The operator and aircraft requirements for the use of 30-NM lateral and 30-NM longitudinal separation standards include approval for Required Navigation Performance (RNP)-4 along with direct controller-pilot communications (DCPC). The use of satellite data link communications involving CPDLC is considered to be DCPC.

2.4. As part of the safety assessment, this document provides verification that the ADS-C requirements contained in ICAO Doc 4444, as they pertain to the application of the 30-NM lateral and 30-NM longitudinal separation minima, are satisfied in Anchorage Oceanic and Offshore Airspace. In addition, this document provides comparisons of important parameter values in the airspace of application to those of ICAO Doc 9689 (reference 2) used in development of the requirements for safe application of the reduced horizontal separation minima under the general assumptions of RNP 4 navigational performance and the use of CPDLC and ADS.

2.5. The safety assessment for the implementation of the 30-NM lateral and longitudinal separation minima contained in this document will consider risk due to loss of lateral separation and longitudinal separation separately. Therefore, estimates of risk of loss for each separation minimum are provided as if the airspace were managed in a strictly strategic manner, without decision support aids of the Ocean21 system. If the resulting lateral and longitudinal collision risk estimates satisfy the TLS, then the 30-NM lateral and longitudinal separation standards are considered “safe”.

3. Description of Anchorage Oceanic and Offshore Airspace

3.1. Figure 1 shows the location of Anchorage Oceanic and Offshore Airspace. The western boundary of Anchorage Oceanic and Offshore Airspace borders the Fukuoka FIR. Air Traffic Services (ATS) for the Fukuoka FIR are provided by Japan’s Civil Aviation Bureau (JCAB) and Air Traffic Management Center (ATMC). The southern boundary of Anchorage and Offshore Airspace borders the Oakland FIR. The U.S. FAA is the ATS provider for the Oakland FIR. The northern boundary of Anchorage and Offshore Airspace borders airspace controlled by the Russian Federation.

3.2. The planned implementation of the reduced horizontal separation minima will include eligible operations within Anchorage and Offshore Airspace. In addition, the planned implementation will include eligible operations conducted within other areas Anchorage and Offshore Airspace where the ATOP automation system provides ATC with the necessary decision-support tools. Additionally, it is envisioned that pairs of aircraft to which reduced separation has been applied will transition the boundary between Anchorage and Offshore Airspace and the Fukuoka FIR intact as both facilities will support common separation minima. Figure 2 presents the locations of the aircraft/pilot reported positions obtained through the Ocean21 archive data for the month of December 2010.

3.3. An estimated average of 440 flights per day operate within Anchorage and Offshore Airspace. A majority of these flights are conducted within the domestic/continental portions of the airspace. An estimated average of 152 flights per day operates within the oceanic portion of the Anchorage Oceanic and Offshore Airspace.

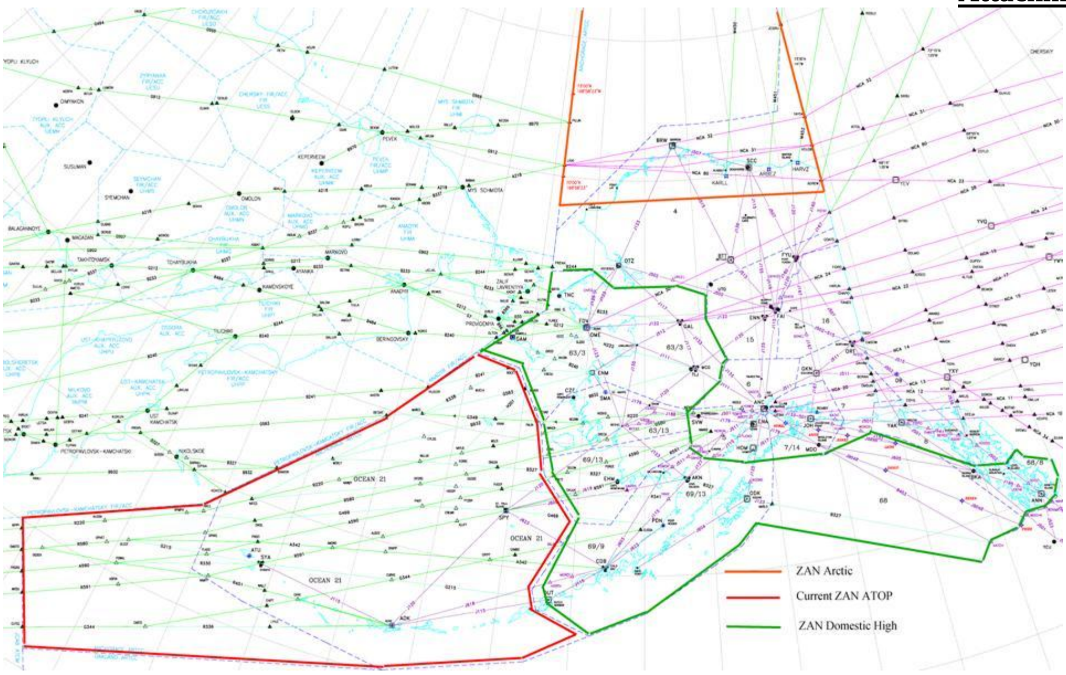

Figure 1. Anchorage Airspace

3.4. The principal traffic flows within the Anchorage Oceanic and Offshore Airspace are contained on the North Pacific (NOPAC) Route System. This route system is comprised of five main airways used by aircraft traveling between North America and Northern Asia. Figure 3 shows the usage of each of the NOPAC routes for operations entering/exiting Anchorage Oceanic and Offshore Airspace at the Fukuoka boundary.

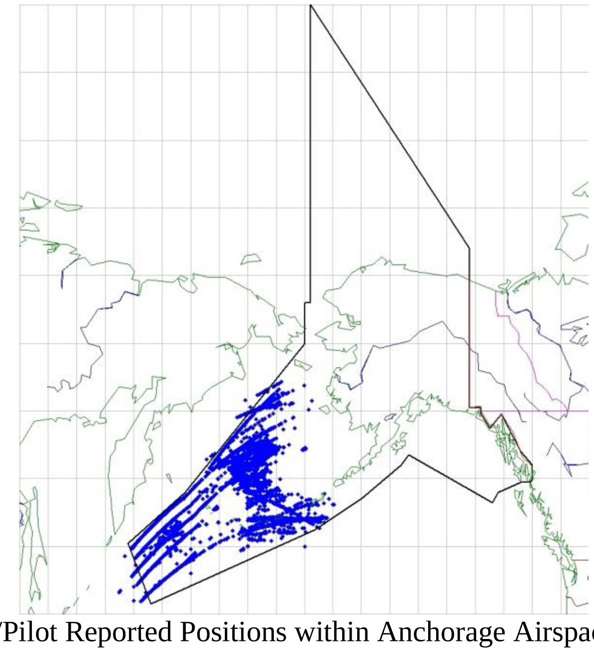

Figure 2. Aircraft/Pilot Reported Positions within Anchorage Airspace – December 2010

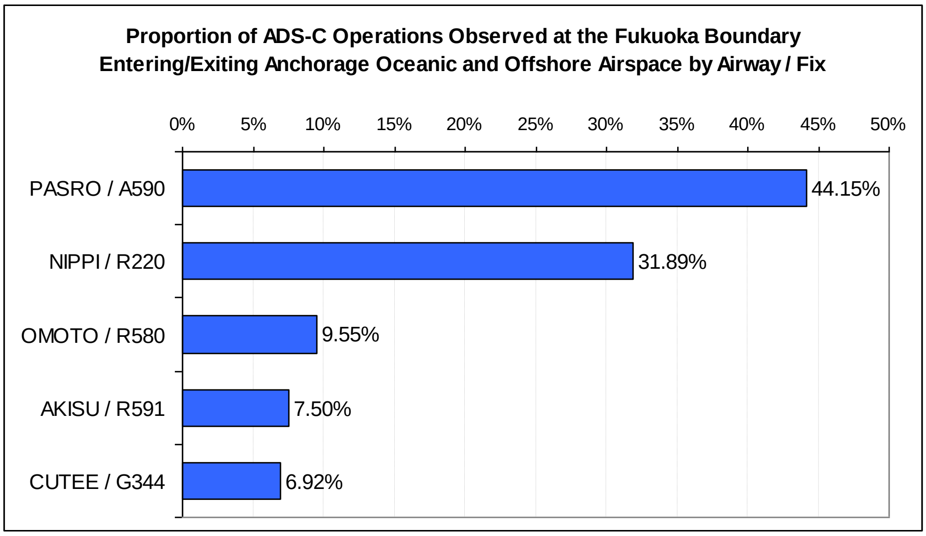

Figure 3. Proportions of ADS-C Operations by Airway Fix/Route in Anchorage and Offshore Airspace – September 2010 – August 2011

3.5. Three of the five main airways in the NOPAC are one-way routes. Airway R220 and R580 are westbound routes. Airway A590 is an eastbound route. The remaining two routes, R591 and G344, allow for bi-directional traffic using flight level allocation rules. The eastbound route A590 has the largest percent of ADS-C traffic in Anchorage Oceanic and Offshore Airspace with 44.15 percent.

3.6. The top 90 percent of operators, in terms of number of operations, observed within Anchorage Oceanic and Offshore Airspace during the period September 2010 through August 2011 are shown in Figure 4. The top operator, Korean Air Lines Co Ltd. (KAL), accounts for approximately ten percent of the observed operations in the sample. An additional 80 percent of the operations in the sample are attributed to twenty operators.

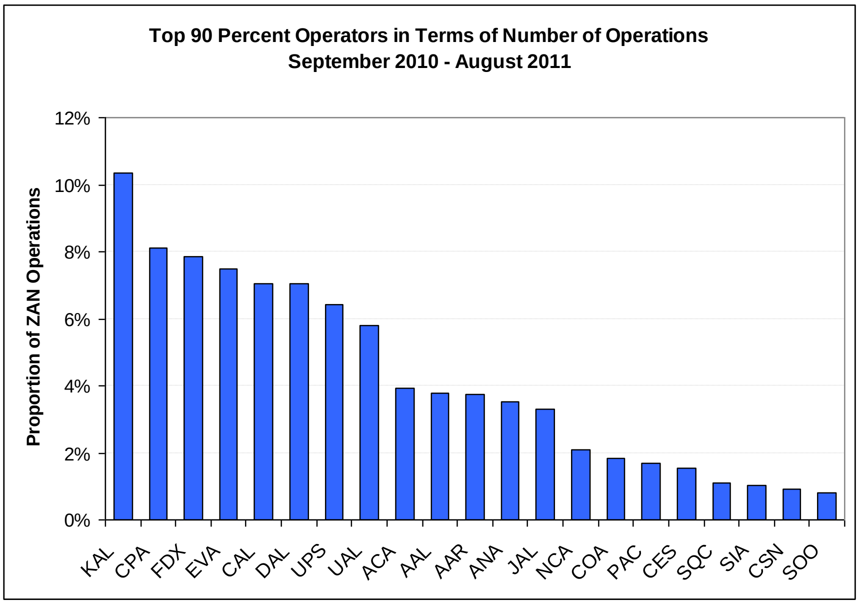

Figure 4. Top 90 Percent of Operators, in Terms of Number of Operations, Observed within Anchorage Oceanic and Offshore Airspace, September 2010 – August 2011

3.7. The top 90 percent of aircraft types observed in Anchorage Oceanic and Offshore Airspace during the period September 2010 through August 2011 in terms of number of operations are shown in Figure 5. The B763, B744, B772 aircraft types account for roughly 17, 14, and 12 percent of all operations conducted within Anchorage Oceanic and Offshore Airspace.

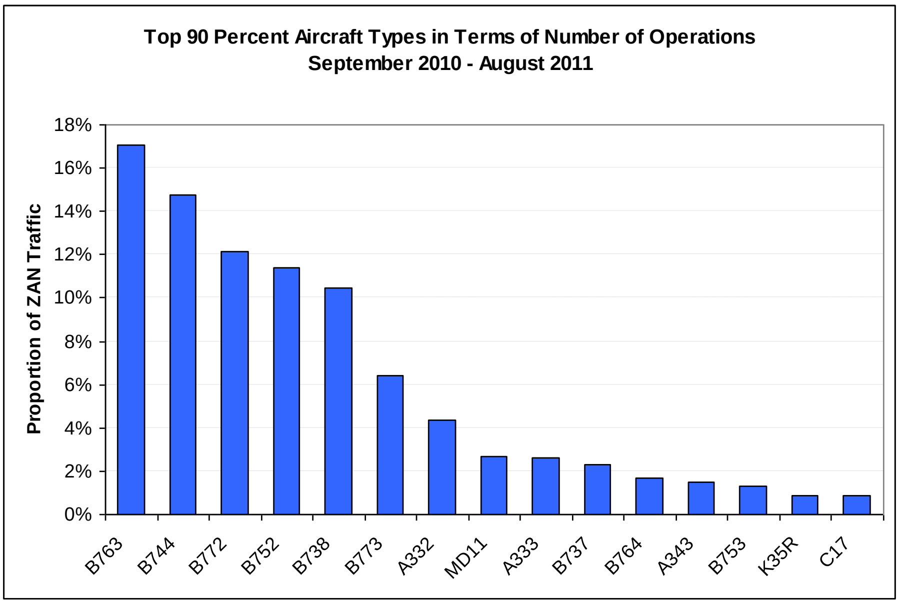

Figure 5. Top 90 Percent Aircraft Types Observed within Anchorage Oceanic and Offshore Airspace in Terms of Number of Operations – September 2010 through August 2011

3.8. The top 20 operator-aircraft-type combinations observed in Anchorage Oceanic and Offshore Airspace are shown in Figure 6. The data in Figure 6 relates only to those operations utilizing ADS-C for position reporting. The top two operator/aircraft type combinations, contributing nine and eight percent, respectively, to the total observed operations are China Airlines (CAL) / B744, and Cathay Pacific (CPA) / B744. The data presented in Figure 6 represents roughly 78 percent of all ADS-C operations conducted within Anchorage Oceanic and Offshore Airspace during the period of September 2010 through August 2011.

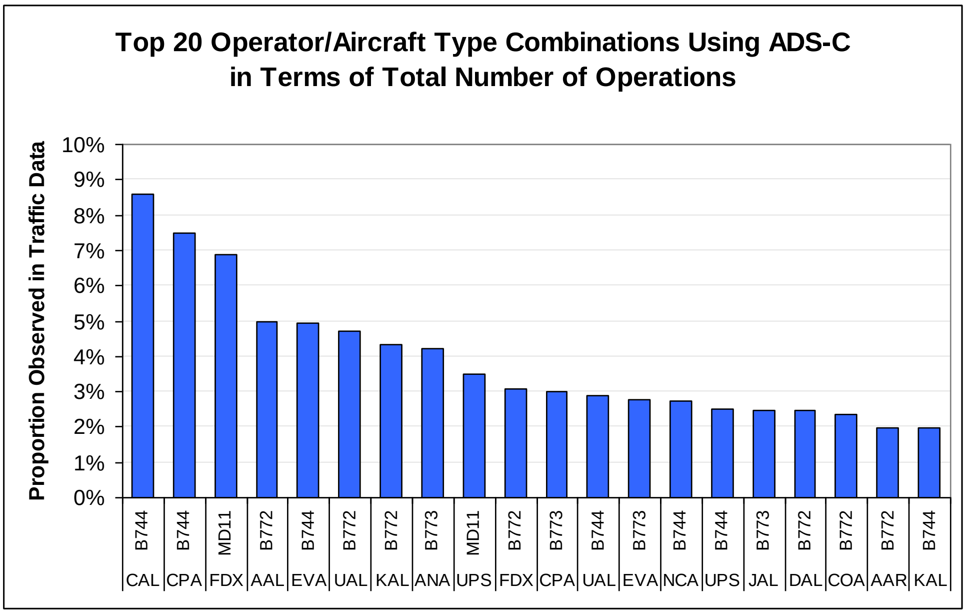

Figure 6. Top 20 Operator-Aircraft Type Combinations Using ADS-C, in Terms of Number of Operations, Observed within Anchorage Oceanic and Offshore Airspace, September 2010 through August 2011

3.9. Table 1 contains a summary of the filed RNP values observed for Anchorage Cceanic and Offshore Airspace. These data were obtained through the aircraft filed flight plans for the time period of September 2010 through August 2011. Table 1 contains the proportions of flight operations related to each observed RNP value. Also captured are the number of flight operations for which there was no RNP value observed in the filed flight plan or no flight plan contained in the archived data. As shown in Table 1, most of the flights conducted within the Anchorage Oceanic and Offshore Airspace are approved for RNP 10 operations. Approximately 25 percent of operations conducted within Anchorage Oceanic and Offshore Airspace file as RNP 4 approved.

Table 1. Proportion of Operations by Filed RNP Status within Anchorage Oceanic and Offshore Airspace, September 2010 through August 2011

RNP Status	Count	Proportion
RNP 10	39,251	70.71%
RNP 4	13,853	24.96%
RNP 5	1,389	2.50%
RNP 1	295	0.53%
Unknown or no RNP filed	722	1.30%
TOTAL	55,510	

The proportion of all operations in Anchorage Oceanic and Offshore Airspace using ADS-C for position reporting is roughly 75.5 percent for the time period of September 2010 through August 2011. The total number of unique ADS aircraft operations observed in Anchorage Oceanic and Offshore Airspace from September 2010 through August 2011 is 41,993. The proportions of ADS aircraft traveling eastbound and westbound are nearly equivalent at 49.7 and 50.3 percent, respectively.

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

4.1. As noted above, 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 standards.

4.2. Appendix A contains the operator-aircraft type combinations of flights filing RNP 4 in the flight plan and utilizing ADS-C to report position within Anchorage Oceanic and Offshore Airspace from September 2010 to August 2011. This subset of traffic represents the operations eligible for 30-NM lateral and longitudinal separation minima within Anchorage Oceanic and Offshore Airspace. The percentages listed in Appendix A represent the proportions of operations for the respective operator-aircraft type combinations.

4.3. The operator-aircraft combination representing the largest proportion of eligible operations for the 30-NM lateral and longitudinal separations, shown in Appendix A, are the Cathay Pacific B744 operations followed by the United Airlines B772 operations. Together, these two operator-aircraft type combinations represent roughly 36 percent of operations that are eligible for the application of the reduced horizontal separation standards.

4.4. Table 2 displays the proportions of aircraft types, in terms of numbers of operations, observed using ADS-C for position reporting and indicating RNP 4 in the filed flight plan in Anchorage Oceanic and Offshore Airspace. These data were collected for the time period of September 2010 through August 2011. The top 2 aircraft types, B747-400 and B777-200, represent approximately 79 percent of the operations of those utilizing ADS-C and indicating RNP 4 in the filed flight plan in Anchorage Oceanic and Offshore Airspace. The top 3 aircraft types shown in Table 2 represent nearly 90 percent of eligible operations for the application of the reduced horizontal separation standards.

Table 2. Aircraft Types Indicating RNP 4 in the Filed Flight Plan and Utilizing ADS-C in Anchorage Oceanic and Offshore Airspace

Aircraft Type	Count	Proportion
B744	5,875	44.41%
B772	4,524	34.20%
B773	1,446	10.93%
MD11	967	7.31%
K35R	112	0.85%
A332	73	0.55%
C17	62	0.47%
GLF5	52	0.39%
B737	31	0.23%
A343	24	0.18%
C5	22	0.17%
GLF4	15	0.11%
A388	10	0.08%
B752	7	0.05%
C135	5	0.04%
A333	2	0.02%
B742	2	0.02%
TOTAL	**13,229**	

5. Safety Assessment Methodology

5.1. In accordance with the requirements and guidance of references 1, 2, and 3, the safety assessment described in this document provides estimates of the risk of collision which will pertain when 30-NM lateral and longitudinal separation minima are applied in Anchorage Oceanic and Offshore Airspace and compares this risk to the specified Target Level of Safety (TLS).

5.2. As stated in reference 2, Paragraph 3.2.1, the value of the TLS which applies to both the lateral and longitudinal dimensions is 5 x 10^{-9} fatal accidents per flight hour (fapfh).

5.3. Estimation of collision risk in this safety assessment is carried out using the general collision risk model, as described in reference 2, which has different forms for the lateral and longitudinal dimensions. No explicit derivations of these two model forms will be provided in this safety assessment. The interested reader is referred to the portions of reference 2 for the technical details of the assumptions and mathematical details of the models.

5.4. Given the complexities of the Ocean21 features supporting separation maintenance, estimating collision risk with consideration for this system aiding the controller would require detailed modeling and simulation. This process would require a great deal of data with the system in full operation in Anchorage Oceanic and Offshore Airspace.

5.5. The risk estimation approach adopted by the FAA Technical Center is to estimate risk without taking into account the risk-reduction features of the Ocean21 decision support system. If risk were to meet the TLS under these conditions, particularly the lateral collision risk, then it would be reasonable that the risk with the decision support system in place would be less and the safety margin would be larger than predicted in comparison to the TLS.

5.6. The specific risk estimation approach used is to assume that all the traffic in Anchorage Oceanic and Offshore Airspace operates on parallel routes, including the traffic not operating on the NOPAC route system. This assumption leads to higher estimates of risk than would be the case if aircraft tracks did lead to long durations of operation at minimum separation.

5.7. These two assumptions – estimation of risk without benefit of risk reduction due to intervention resulting from the Ocean21 controller decision support system and use of parallel-tracks – leads to risk estimates which are conservative – that is to say, higher – than would be the case if these assumptions were not made and the actual situation with respect to decision support system and aircraft tracks were taken into account.

5.8. Ocean21 risk-reduction features are included in discussions as appropriate descriptive information on this topic is meaningful.

5.9. **Lateral Collision Risk Model**

5.9.1. The form of the lateral collision risk model applicable to assessing the risk, N_{ay}, of a 30-NM lateral separation standard from Appendix 15 of reference 2 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 3.

Table 3. Lateral Collision Risk Model Parameters

Term	Definition
S_x	Nominal distance defining proximity of aircraft on adjacent parallel track to a

Term	Definition
	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

5.10. Longitudinal Risk Model

5.10.1. 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 a 30-NM longitudinal separation standard is given in references 6 and 7. Assuming that the aircraft pair are on the same ground track, the collision risk during a time interval $[t_0,t_1]$ is given by

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

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

5.10.3. The term for the horizontal overlap probability (HOP) considers the along-track and cross-track position errors of two longitudinally separated aircraft. An equation for HOP for operations on the same ground track (e.g. angle of zero degrees) is given in reference 6 as:

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

5.10.4. In equation (3) $D_x(t)$ is the distance between the aircraft pair and λ is the scale parameter for the along-track and cross-track position error distributions. Along-track and cross-track deviations are modeled with a double exponential distribution. The maximum acceptable scale parameter, λ, for a specified RNP value or a navigation accuracy value of k is $\frac{k}{-\ln(0.5)}$ (reference 5). The application of 30-NM longitudinal separation standard requires aircraft to navigate to the 4-NM/95 percent accuracy criteria of RNP 4. Actual aircraft performance for aircraft utilizing GPS for navigation is much better than RNP 4. To model the more accurate performance of GPS navigation correctly, the value of k for these aircraft is 0.3-NM. Reference 9 also uses this parameter to model GPS aircraft. The actual navigation performance for remaining aircraft operations eligible for the 30-NM longitudinal separation uses the required performance for RNP 4 (k = 4-NM).

5.10.5. 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. Reference 6 considers three cases under an ADS environment and provides the components for τ for each case. The components for each of the three cases are replicated here for clarity.

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

- 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 5).

- When the ADS periodic report is lost or takes longer than 3 minutes (Table 6).

5.10.6. All of the components for τ used in the collision risk estimation for Anchorage Oceanic and Offshore Airspace conform to those provided in Tables 4 - 6 except for the CPDLC uplink time. Reference 6 assigns a static value of 90 seconds to the CPDLC uplink transit time. This document uses an empirical distribution for the CPDLC uplink transit time based on observed performance in Anchorage Oceanic and Offshore Airspace. This distribution is explained in proceeding sections of this document.

Table 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 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 6. Components of τ when ADS 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

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

Table 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

Term	Definition
$[t_0,t_1]$	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
τ	Controller intervention buffer which is the time for the controller to intervene, convey instructions to the pilot and for the pilot to react and cause the aircraft to achieve a change of trajectory sufficient to ensure that a collision will be averted

5.10.8. Interpretation of the parameters in Tables 3 and 7 are given later in this document, several of which have values that are readily obtained. The next section describes the sources of data used to estimate several of these parameters.

6. Data Sources Used for the Safety Assessment

6.1. Several data sources are used to assist in conducting this safety assessment. These data sources provide insight into the operations of Anchorage Oceanic and Offshore Airspace, and support the estimation of values for several of the parameters shown in Tables 3 and 7.

6.2. Safety Databases

6.2.1. A group of FAA databases, collectively called the Air Traffic Quality Assurance Database (ATQA), contains information regarding all reported instances of operational errors made by flight crews or air traffic controllers, with such reports being compulsory for FAA personnel witnessing the errors. The FAA Technical Center is provided with extracts of relevant data from these databases.

6.2.2. The Anchorage ARTCC is required to report Gross Navigation Errors (GNE), height errors, time (longitudinal) errors, and Special Area of Operations (SAO) verification in oceanic airspace through FAA Order 7110.82D. The FAA Technical Center receives reports of these events and uses the data for statistical analysis.

6.2.3. The Pacific Approvals Registry and Monitoring Organization (PARMO), a service provided by the FAA Technical Center, serves as the En-route Monitoring Agency (EMA) and Regional Monitoring Agency (RMA) for Anchorage Oceanic and Offshore Airspace. In the Asia and Pacific region, established EMAs and RMAs report to the ICAO Asia and Pacific Regional Airspace Safety Monitoring Advisory Group (RASMAG) which, in turn, reports to the ICAO Asia and Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG). In order to produce the required safety monitoring reports, EMAs and RMAs must collect appropriate event data from the airspace. As part of this process, the Anchorage ARTCC sends the PARMO monthly deviation reports.

6.2.4. All of relevant material from ATQA, FAA Order 7110.82D, and the PARMO monthly reports were assembled by the FAA Technical Center for the time period of September 2010 through August 2011 for use in this safety assessment.

6.3. **Ocean21 Archived Data**

6.3.1. As previously noted, the Ocean21 automation system became fully operational in Anchorage Oceanic and Offshore Airspace on 1 March 2007. Since this time, the system operations experts at Anchorage ARTCC have provided the Technical Center with all of the archived Ocean21 operations data. The supporting data for this safety assessment covers the one-year time period of September 2010 through August 2011. These data consist of all the flight plans, and the HF, CPDLC, and ADS-C communication messages provided from the comprehensive data reduction and analysis (DR&A) capabilities of Ocean21.

6.3.2. Table 8 describes the types of ADS-C uplink messages contained within the Ocean21 DR&A data and Tables 9A and 9B cover ADS-C downlink messages. Each table provides the names of the various message types, the corresponding three-letter identifiers used as shorthand, and descriptions of the messages. In addition, there are brief examples of the contents for certain message types.

6.3.3. As noted in the Background section of this document, safe introduction of the 30-NM lateral and longitudinal separation minima require that CPDLC and ADS-C be operational in the airspace and that the ADS function have certain properties, in accordance with reference 1. In particular, there is the requirement for a 14-minute periodic ADS-C reporting rate, and a request for a position update if a periodic ADS position report is delayed by three minutes or more. The message types in Table 8 demonstrate that Ocean21 is capable of full compliance with these requirements.

6.3.4. Entry four in Table 8, identifier ‘PER’, establishes the contents of the basic ADS-C message, identifier, ‘BAS’ (Table 9A), to be transmitted by an aircraft when engaged in an ADS-C contract. Ocean21 detection of RNP 4 approval in an aircraft’s flight plan results in transmission of a PER message setting the ADS periodic reporting rate, identifier ‘ITV’, to 14 minutes.

6.3.5. Ocean21 monitors automatically the interval between receipts of BAS reports for each aircraft under contract. Should an ADS-C basic report be overdue by more than 3 minutes relative to the value of ITV established with the aircraft, Ocean21 automatically sends a PER uplink message with ITV=0, thus requiring that the aircraft transmit a BAS message immediately on receipt of the uplink message.

Table 8. ADS Uplink Message Types and Descriptions

Message Type	Identifier	Description
Cancel ADS contract number N with an aircraft	CCR	Identifies Ocean21-initiated ADS contract number to be cancelled with an aircraft
Cancel all contracts and terminate ADS connection	CTC	Cancels all contracts with an aircraft and terminates ADS connection
Contract number N has total and type of events included	EVT	Contains the total number of contracts and the listing of types and parameters of events in the contract (for example, waypoint reports, lateral deviation bound, and vertical rate bound)
Contract number parameters	PER	Identifies various ADS reporting parameters to be included in the basic (BAS) periodic report to be provided automatically by an aircraft at a fixed interval (for example, the reporting interval in seconds, whether or not aircraft-referenced, earth-referenced or meteorological information is to be included in the downlink message – see table 9A for details of the information)

Table 9A. ADS Downlink Message Types and Descriptions

Message Type	Identifier	Description
ADS disconnect		Disconnect ADS and provide reason for breaking connection (for example, “ADS Disconnect: Normal disconnect”)
Acknowledge	ACK	Acknowledge an ADS uplink message (for example, “ACK: Request for contract 2”)
Basic Periodic Report	BAS	Contains aircraft position report and other information specified in the periodic contract – see PER message in table 8 – (for example, Position report “BAS: Pos = lat/long Alt = n1 feet Time = hh:mm:ss Multiple NAV units Accuracy < 0.25 nm TCAS is ON” Next and next+1 waypoints: “PRR: Pos = lat/long Alt = n2 feet ETA= hh:mm:ss Pos = lat/long Alt = n3 feet Earth-referenced current flight data: “ERF: Track = m degrees GS (groundspeed) = v knots VR (vertical rate) = k ft/min Aircraft-referenced current flight data: “ARF: Heading = n degrees Speed = r Mach VR (vertical rate) = k ft/min Meteorological data “MET: Wind dir = j degrees Wind spd = r knots Temp = d C

Table 9B. ADS Downlink Message Types and Descriptions - Concluded

Message Type	Identifier	Description
Lateral deviation	LDC	Report of a lateral deviation from planned routing greater than that specified in the event contract – PER, table 8 (for example,

Message Type	Identifier	Description
		"LDC: Pos = lat/long Alt = n1 feet Time = hh:mm:ss Multiple NAV units Accuracy < 0.25 nm TCAS is ON")
Negative Acknowledgment	NAK	Negative acknowledgment; provides a reason for negative ACK (for example, "NAK: Request for contract 0 is rejected due to duplicate request number")
Vertical rate change	VRC	Contains aircraft position and vertical rate change greater than set in event contract – EVT table 8 – (for example, "VRC: Pos = lat/long Alt = n1 feet Time = hh:mm:ss Multiple NAV units Accuracy < 0.25 nm TCAS is ON" ERF: Track = m degrees GS (groundspeed) = v knots VR (vertical rate parameter) = i ft/min")
Waypoint change	WPC	Contains position report of aircraft as it crosses a defined waypoint in its flight plan– EVT, table 8 – (for example, "WPC: Pos = lat/long Alt = n1 feet Time = hh:mm:ss Multiple NAV units Accuracy < 0.25 nm TCAS is ON" PRR: Pos = lat/long Alt = n2 feet ETA= hh:mm:ss Pos = lat/long Alt = n3 feet")

6.3.6. The Ocean21 archived data also contains the filed flights plans and the HF and CPDLC messages from all the flights operating within Anchorage Oceanic and Offshore Airspace. An example of each is shown in Table 10.

Table 10. Examples of Archived Data from Ocean21: ICAO Filed Flight Plans, HF, CPDLC Messages

Message Type	Example from Ocean21 Archived Data
HF Position Report	FI CAL005/OV 35N150W 0155 F320/EO 33N160W 0256/NP 32N170W
CPDLC Position Report	POSITION REPORT Pos: 2504N14325W Time: 0018 Alt: F390 Next Fix: FABBO Time at Next Fix: 0056 Next Fix Plus One: FANTO Time at Destination: 0227 Temp: -52 C Winds: 300 Degrees at: 032 Knots Speed: M084 ReportedWaypointPosition : FADER ReportedWaypointTime: 0016 ReportedWaypointAltitude: F390 DEVIATING R 001 NM OF ROUTE
ICAO File Flight Plan	FPL-UAL830-IS -B772/H-SXWDHIJRYZ/CD -RJGG0655 -N0497F330 DCT CBE DCT KAZKI DCT KZE/M084F330 DCT PETAL OTR14 VACKY OTR13 SEALS DCT 35N150E/M084F350 35N160E 37N170E 40N180E 42N170W 42N160W/M084F370 42N150W 42N140W 41N130W DCT UNVER/N0482F370 DCT ENI J|143 PYE GOLDN4 -KSFO0827 KOAK -EET/KZAK0217 KZOA0739 REG/N798UA SEL/ASFK DAT/SV NAV/RNP 10 RALT/RJAA PMDY PACD CYVR RMK/TCAS EQUIPPED 180 MIN ACFT

7. Examination of Aircraft Operations in Anchorage Oceanic and Offshore Airspace

7.1. The packing of aircraft in Anchorage Oceanic and Offshore Airspace is important to risk estimation. Definitive information on aircraft packing is gained from the history of inter-aircraft separations operating within Anchorage Oceanic and Offshore Airspace. The separation of aircraft pairs are examined upon entry into the airspace as well as during the operation within the airspace.

7.2. To examine the aircraft-packing in Anchorage Oceanic and Offshore Airspace, separations between aircraft pairs are observed. The boundary crossing-times, available in the archived Ocean21 data are analyzed for aircraft pairs entering airspace. These data were examined for the twelve-month period of September 2010 through August 2011. 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.

7.3. Two flights 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 a time-over a common position within 19 minutes of each other. The longitudinal separation between proximate ADS-C aircraft within Anchorage Oceanic and Offshore Airspace is observed in terms of distance. The distance intervals are organized into bins of 1-NM as presented in Figure 7. 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.

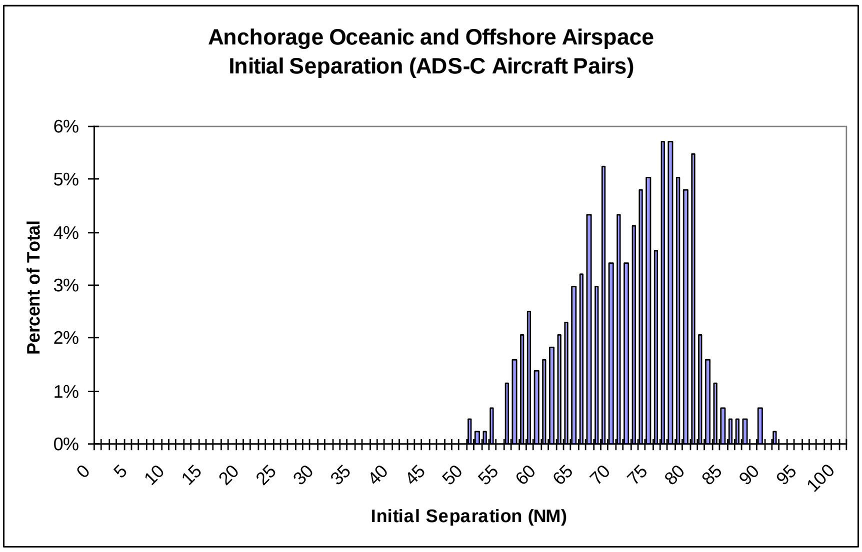

Figure 7. Relative Frequency Distribution of Initial Separation between Proximate ADS-C Operating within Anchorage Oceanic and Offshore Airspace

7.4. The data in Figure 7 shows evidence of the application of the current 50-NM longitudinal separation minimum in Anchorage Oceanic and Offshore 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 7.

8. Analysis of Data Retrieved from Safety Databases

8.1. As previously noted, the ATQA safety databases, FAA 7110.82D, and PARMO monthly reports were examined for the period 1 September 2010 through 31 August 2011 in a search for events of possible importance to the application of the 30-NM lateral and longitudinal separation minima.

8.2. The search criteria used on the ATQA safety database are deliberately made broad to minimize the possibility of missing such events. These search criteria have previously been shown to capture related events for similar studies of oceanic operations. As a consequence, all Pacific oceanic reports from ATQA were examined initially for the stated period. Search criteria for ASRS reports were “link,” “screen,” “ocean,” “CPDLC,” “FANS” and “Pacific.” The inclusion of “screen” in the search criteria was intended to capture all reports of possible problems with using the display forming part of the FANS flight deck suite, which had been identified as a problem with the use of FANS equipment in the latter 1990’s.

8.3. The data sources produced four incident reports, relating to longitudinal and lateral events. A summary of each of these four events is provided in Table 11.

Table 11. Summary of Reports Reviewed in Connection with Safety Assessment

Report Number	Date	Facilities Affected	Systematic / Random	Cause
ZOAC10D008	10/28/2010	ZAN /ZAK	Random	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility
ZOAc11E002	2/1/2011	ZAN /ZAK	Random	ATC system loop error (e.g. ATC issues incorrect clearance, Flight crew

Report Number	Date	Facilities Affected	Systematic / Random	Cause
				misunderstands clearance message etc
PALCZAN11001	3/2/2011	ZAN	Random	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.)
NA	9/5/2011	ZAN	Random	Flight crew deviate without ATC Clearance

8.4. Reports of these types will continue to be monitored by the FAA Technical Center and reported to the ICAO RASMAG and FAA Oceanic Separation Reduction Working Group (OSRWG) for consideration.

8.5. Aircraft lateral deviations

8.5.1. The Ocean21 system automatically establishes a 5-NM lateral deviation event contract with all ADS-C aircraft operating in Anchorage Oceanic and Offshore Airspace. This event contract notifies the Ocean21 system and the air traffic controller, via a LDC report, of an aircraft lateral deviation once the deviation magnitude exceeds 5-NM from intended course.

8.6. Weather deviations

8.6.1. Aircraft operators are expected to follow weather deviation procedures within Anchorage Oceanic and Offshore Airspace. A pilot request for a deviation due to weather is sent to the controller via HF or CPDLC while in oceanic airspace, these requests are contained in the archived Ocean21 data. The FAA Technical Center examined the archived CPDLC messages containing pilot requests for weather deviations in Anchorage Oceanic and Offshore Airspace during the time period of May through July 2011. There were 87 flight operations with at least one pilot request for a weather deviation received via CPDLC during the three month period. The corresponding controller responses to these requests were also examined. An unable response was observed for 12 of the 87 flights, the remaining 75 flights were granted the requested weather deviation.

8.6.2. ATC has additional surveillance available for ADS-C aircraft following a weather deviation clearance. The receipt of a LDC report from the aircraft is expected and is used by ATC to confirm the direction of the weather deviation. Once the pilot sends the back-on-route message, the Ocean21 system automatically resets the LDC event contract to 5-NM.

8.6.3. The FAA Technical Center also examined the archived LDC reports for the flights requesting a deviation from course due to weather. The archived ADS-C reports showed that a LDC report was received from 23 of the flight operations granted a weather deviation in the three month sample. Operational experts have noted that a LDC report is generated in reference to the current planned route within the Flight Management System (FMS) on the aircraft. According to the operational experts, when a 5-NM lateral event contract is established, a LDC report will be generated when the aircraft deviates more than the 5-NM from the current FMS course. If the track contained within the FMS is modified for a weather deviation, it is possible that a LDC report will not be generated because the aircraft is not deviating from its' FMS course.

8.6.4. The FAA Technical Center will continue to monitor weather deviations and report the results to the OSRWG for consideration

9. Position Data Collected from Ocean21 Archives

9.1. As will be recalled from the description of Ocean21 operation in Anchorage Oceanic and Offshore Airspace in Section 6.3, the system became fully operational on 1 March 2007 after undergoing extensive preparation. Anchorage automation specialists have provided the Technical Center with all data archived from the system for the period 1 September 2010 through 31 August 2011 for use in conducting the safety assessment.

9.2. Ocean21-recorded ADS-C downlink reports

9.3. The ADS-C downlink message provides an aircraft progress picture of position at the update rate specified in an ADS contract. At least implicitly, requirements for ADS-C in listed references 1 and 2 refer to this fundamental ADS-C message. Thus, it is valuable to examine Ocean21 data sources in order to observe its occurrence.

9.4. Figure 8 shows aircraft locations obtained from ADS-C Basic Periodic Reports transmitted in August 2011. The locations of the five primary airways can be clearly observed in Figure 8. It should be noted that many positions shown in Figure 8 are external to Anchorage Oceanic and Offshore Airspace. These external data were not used in the safety assessment process.

9.5. Figure 8 also shows the approximate locations of radar sites within Anchorage Oceanic and Offshore Airspace – these are shown in red. It is important to consider the locations of the radar sites and the corresponding radar controlled airspace in order to exclude areas of radar coverage from procedural airspace where the reduced separation standards will be applied.

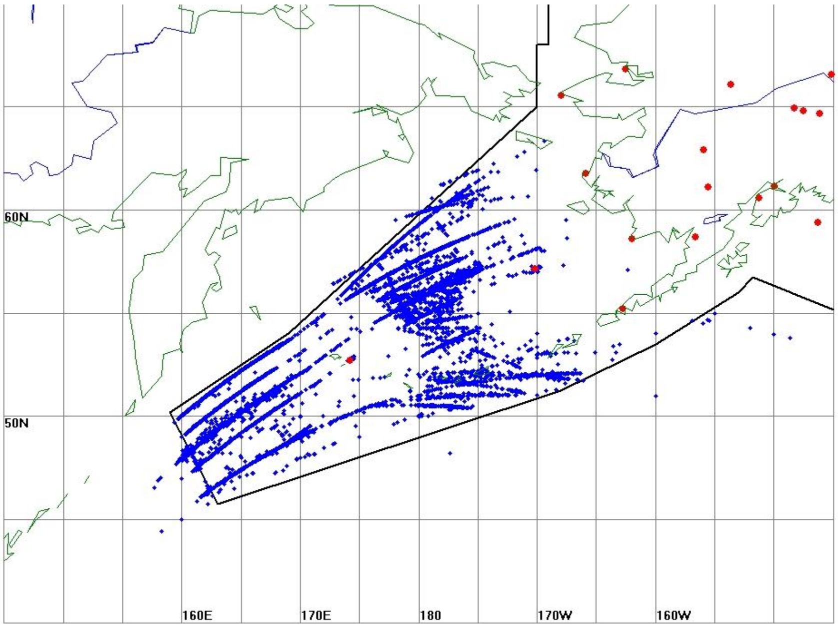

Figure 8. Radar Locations and ADS-C Basic Periodic Reports Positions Obtained from Archived Ocean21 Data – August 2011

10. Data Link Communication Performance

10.1. The ICAO APANPIRG adopted the First Edition of the Global Operational Data Link Document (GOLD) (reference 4) in 2010. The GOLD replaces the FANS 1/A Operations Manual (FOM), which was used throughout the Asia and Pacific (APAC) Region prior to 2010. 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.

10.2. The GOLD describes the necessary data points from the FANS 1/A aircraft communications addressing and reporting system (ACARS) messages to be used for post-implementation monitoring. The GOLD also explains the end-to-end satellite data link communications chain of events as well as the calculation process for the prescribed performance measures; actual communication performance (ACP), actual communication technical performance (ACTP), pilot operational response time (PORT), and ADS-C surveillance latency and specifies the requirements for each performance measure at the 95% and 99.9% levels.

10.3. According to the guidance in the GOLD, the ACP, ACTP and PORT for applicable CPDLC transactions are required to meet the Required Communication Performance (RCP) 240 criteria when sent via satellite and VHF, and are required to meet RCP400 criteria when sent via HF. Similarly, the ADS-C downlink latency is required to meet Required Surveillance Performance (RSP) 180 criteria for ADS-C downlink messages sent via satellite and VHF, and is required to meet RSP400 criteria when sent via HF. For the application of the 30-NM lateral and longitudinal separation minima, the RCP240 and RSP180 criteria are the applicable performance targets for the necessary data link communication performance. Table 12 outlines the appropriate performance targets for the reduced horizontal separation minima.

Table 12. Summary of Data Link Performance Requirements

Performance Measure	Percent of Messages Required to Meet Criteria	RSP180 Criteria (sec)	RCP240 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

10.4. The guidance provided in the GOLD calls for specific CPDLC message sets to be included in the performance monitoring. All uplink communications transfer messages and typical intervention messages such as climb clearances with an expected CPDLC response of either WILCO are assessed. These messages are considered to be intervention messages critical to the communications used when applying reduced separation standards.

10.5. The relevant observed RCP and RSP for all data link operations in Anchorage Oceanic and Offshore Airspace are presented in Appendix B. The data in Appendix B show the aggregate performance from FANS 1/A data link operations in Anchorage Oceanic and Offshore Airspace. The aggregate RSP180 and RCP240 from satellite data link operations in Anchorage comfortably meet the 95 percent criteria. However, when the data are separated by operator, the observed performance varies and a few of the top operators (in terms of number of data link messages) do not meet the 95 percent criteria. This is an area that can be addressed by actions between the appropriate State regulatory authority and the operator.

10.6. The FAA has examined similar data contained in Appendix B from the Oakland FIR since the introduction of the ADS-based separation standards in November 2005. The FAA has determined that the availability of data link communication services in the airspace is the largest concern for ADS-based separations. Because the availability of the data link communication services is critical to the application of ADS-based separation standards, the FAA will continue to monitor the performance of the data link communication services in the Oakland FIR and Anchorage Oceanic and Offshore Airspace.

10.7. Reported Data Link Outages

10.7.1. The FAA Technical Center receives notifications of data link outages from the various communication service providers. Outages may include service interruptions at a specific satellite system, ground earth station, ground communication systems, etc. Table 13 provides a summary of the reported outages affecting operations utilizing both the INMARSAT and IRIDIUM satellite systems for data link communications from February 2010 through September 2011.

Table 13. Summary of Reported Data Link Outages

Date	DSP	Region Affected	Duration (min)	Explanation
1-Feb-10	INMARSAT/ SITA[1]	POR/AOW /AOE	45	Failure of an X25 to IP gateway cluster in Montreal which impacted all connections to the AIRCOM VHF stations, satellite GES and X25 hosts Customer Hosts
3-Feb-10	INMARSAT/ SITA	POR/AOW /AOE	16	Unknown
1-Mar-10	INMARSAT/ ARINC	POR	473	The ARINC GLOBALINK GES XXC located in Santa Paula, CA was impaired due to problems with AERO Voice calls supporting the Pacific Ocean Region (POR).
10-Mar-10	INMARSAT/ ARINC	POR	55	The ARINC AGN AT&T MPLS core node in Livermore, California was out of service due to a major network failure in the AT&T Sonet Network
7-Oct-10	INMARSAT/ SITA	AOW	11	Faulty part caused equipment failure at GES.
1-Feb-11	Iridium	All	38.03	Iridium's SBD service was unavailable.
19-Mar-11	INMARSAT/ SITA	IOR	72	Satellite Voice, Fax and PC Data and Data Services were not available over IOR2 region due to an equipment failure. POR2 was not affected by the interruption.
19-Mar-11	INMARSAT/ SITA	IOR	72	Equipment failure.
24-Mar-11	Iridium		376	The Short Burst Data Systems experienced an unexpected anomaly, SBD messaging may have been delayed and users may have received duplicate messages during this time.
2-Apr-11	INMARSAT/	AOW/AOE	71	Power outage at Aussaguel GES.

[1] SITA = Société Internationale de Télécommunications Aéronautiques

Date	DSP	Region Affected	Duration (min)	Explanation
	SITA			
5-May-11	Iridium	All	89	Some customers utilizing SBD Direct IP for Mobile Terminated messages may have seen messages queued due difficulties connecting with the Iridium server. No messages were lost or service outage experienced; only the possibility of Direct IP Mobile Terminated messages being queued and some difficulty connecting to the Iridium SBD DIP MT server
11-Jul-11	Iridium	All	180	Due to severe thunderstorms which occurred in the vicinity of the Tempe Gateway, customers may have experienced dropped calls and the inability to place or receive calls. Telephony, Paging, SMS messaging, and all Data services may have been affected until the weather anomaly passed. Iridium OpenPort service not affected.
27-Jul-11	INMARSAT/ SITA	IOR	163	Antenna fault at Perth GES.
19-Aug-11	Iridium	All	123	Due to thunderstorms in the vicinity of Tempe Gateway, customers may experience dropped calls and the inability to place or receive calls. Telephony and data serviced may be affected until weather anomaly has passed.
9-Sep-11	Iridium	All	30	SBD Email MT users may have seen intermittent communications issue with Iridium email servers during this timeframe. All messages that were queued were sent.
9-Sep-11	Iridium	All	645	Iridium data link ACARS service is now back to normal. The root cause for the anomaly is still under investigation.
11-Sep-11	Iridium	All	66	During the time frame some customers may have experienced service degradation. All services at this time are back to normal operation.
14-Sep-11	Iridium	All	600	Due to severe thunderstorms in the vicinity of the Tempe Gateway, customers may experience dropped calls and the inability to place or receive calls. Telephony, Paging, SMS messaging, and all Data services may be affected until the weather anomaly has passed. Iridium Open Port service is not affected.

10.8. Since the implementation of ADS-based separation standards in the Oakland FIR, the FAA has observed periods of poor performance in the data link communication services. During these periods, the FAA temporarily discontinued 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.

10.9. Overdue ADS Periodic Reports

10.9.1. The FAA Technical Center examines the aircraft ADS-C periodic reports in the archived data and identifies cases of overdue reports. The numbers of flights with at least one overdue ADS-C periodic report were examined. Further analyses are done to examine the automated/manual controller response to an overdue report. Table 14 contains a listing of the number of flights using ADS-C with at least one missing ADS-C periodic report by month over the time period of September 2010 through August 2011. The FAA Technical Center regularly monitors and reports these events to OSRWG.

Table 14. Overdue ADS-C Reports in Anchorage Oceanic and Offshore Airspace

Month	Number of Operations with Overdue ADS-C Reports	Number of Operations Using ADS-C	Proportion
Sep-10	104	3301	3.15%
Oct-10	130	3177	4.09%
Nov-10	66	3216	2.05%
Dec-10	115	3753	3.06%
Jan-11	118	3410	3.46%
Feb-11	70	3092	2.26%
Mar-11	93	3545	2.62%
Apr-11	70	3447	2.03%
May-11	75	3514	2.13%
Jun-11	64	3524	1.82%
Jul-11	92	4069	2.26%
Aug-11	66	3944	1.67%
Average	89	3499	2.55%

10.9.2. The summary data provided in Table 14 show that approximately 2.6 percent or 89 flight operations per month in the Anchorage Oceanic and Offshore Airspace have at least one overdue ADS-C report.

10.9.3. The longitudinal collision risk model used in this safety assessment and developed in reference 6 considers the case where an ADS report takes longer than 3 minutes and is considered to be lost (see Table 6). Reference 6 conservatively assumed that an ADS report would be lost 5 percent of the time. The longitudinal safety assessment contained in this document also assumes a 5 percent rate for this case, as our empirical data still show this to be a conservative estimate.

11. Ocean21 Decision-Support Features Important to the Application of the 30-NM Lateral and Longitudinal Separation Standards

11.1. The Ocean21 system provides many enhancements to the application of ATC in Anchorage Oceanic and Offshore Airspace. Several of these are particularly important to use of the 30-NM lateral and 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.

11.2. Ocean21 Display

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

11.3. Ocean21 Conflict Probe

11.3.1. Upon receipt of an ADS-C report from an aircraft or controller request for examination of a modification to an aircraft's current flight plan, the system automatically looks for conflicts between aircraft trajectories, or violations of applicable separation minima, between the aircraft and all others in the airspace, using a preset interval look-ahead time. If a conflict is uncovered, the controller is notified on the Ocean21 display by means of flashing colored leader lines from the two aircraft in conflict, with intersection of the lines at the projected point of conflict. The probe is informed not only by previously received ADS position reports from all aircraft under ATC, but also by meteorological forecasts which are updated appropriately to the latest version received at the Anchorage ARTCC.

12. Parameters For the Collision Risk Models

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

13. Parameters Common to the Lateral and Longitudinal Collision Risk Models

13.1. Aircraft length, wingspan and height - λ_x, λ_y and λ_z

13.2. The length, wingspan and height of the average aircraft observed in Anchorage Oceanic and Offshore Airspace are obtained from the aircraft types listed in Table 2 of this document. 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 (see Table 2). Table 15 shows the aircraft length, wingspan, and height, expressed in NM, of the aircraft types listed in Table 2. The weighted average aircraft length, wingspan, and height, expressed in NM, are 0.036315, 0.033141 and 0.010099, respectively.

Table 15. Weighted Size of the Aircraft Eligible for the Reduced Separation Standards in Anchorage Oceanic and Offshore Airspace

Aircraft Type	Proportion	Length (NM) λ_x	Wingspan (NM) λ_y	Height (NM) λ_z
B744	44.41%	0.038153	0.034793	0.010478
B772	34.20%	0.034409	0.032900	0.009998
B773	10.93%	0.039903	0.032883	0.009989
MD11	7.31%	0.033261	0.028062	0.009465
K35R	0.85%	0.022408	0.021544	0.006857
A332	0.55%	0.031050	0.032560	0.009390
C17	0.47%	0.028639	0.027937	0.009066
GLF5	0.39%	0.015870	0.015390	0.004250
B737	0.23%	0.018158	0.018528	0.006775
A343	0.18%	0.034370	0.032560	0.009090
C5	0.17%	0.040660	0.036660	0.010690
GLF4	0.11%	0.014525	0.012797	0.003996

Aircraft Type	Proportion	Length (NM) λ_x	Wingspan (NM) λ_y	Height (NM) λ_z
A388	0.08%	0.039417	0.043089	0.013013
B752	0.05%	0.025550	0.020544	0.007323
C135	0.04%	0.027808	0.021544	0.006857
A333	0.02%	0.034370	0.032560	0.009090
B742	0.02%	0.038121	0.032181	0.010421

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

13.3.1. The probability of vertical overlap required to estimate longitudinal risk is that associated with two co-altitude aircraft. The value used in this safety assessment, 0.538, has been used previously for other Pacific risk assessments and reflects the positive effect of the RVSM on height-keeping performance.

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

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

14. Parameters Used Only in Estimation of Lateral Risk

14.1. Average absolute relative along-track speed of two-aircraft as they pass on parallel tracks - $\overline{|\dot{x}|}$

14.1.1. Aircraft operations on parallel tracks are independent of application of Mach number technique or any other actions by ATC to regulate the relative speed between aircraft. As a result, the relative speed between a typical pair of co-altitude aircraft on adjacent tracks reflects the range of speeds of individual aircraft in the airspace. The FAA Technical Center assembled the reported ground speeds, obtained from the ADS-C basic reports, from 12,227 RNP 4 operations in Anchorage Oceanic and Offshore Airspace over the period September 2010 through August 2011. The detailed results are provided in Appendix C

14.1.2. 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 with the entries in Appendix C are weighted according to the proportions of entries. These weighted speed differences are averaged, producing a value of 17 knots for the average relative along-track speed of a pair of co-altitude on laterally adjacent routes.

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

14.2.1. This parameter describes the relative speed of two aircraft as they lose all planned lateral separation. Since the basic track-keeping accuracy of aircraft equipped with navigation systems using GPS-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 – estimation of lateral risk proceeded with a value of 48 knots for the relative across-track speed parameter, a value corresponding 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 Anchorage airspace.

14.3. Same- and Opposite-Direction Lateral Occupancies – $E_y(same)$ and $E_y(opp)$

14.3.1. 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 the might be an aircraft proximate. A typical example of an airspace with high occupancy is that containing the North Atlantic Organized Track System, where diurnal flows of 400 or more aircraft pack turbojet enroute flight levels for the average 3.5 hour transit between North America and Europe. Post-RVSM-implementation North Atlantic same-direction lateral occupancy estimates dropped in value initially as aircraft were dispersed across more available flight levels, but have been increasing recently as more aircraft use the airspace, with the current estimate of approximately 1.1.

14.3.2. 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.

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

14.3.4. Empirical evidence of NOPAC aircraft pairs operating on the same flight level while separated by the current lateral separation standard, 50-NM, served as the data for the occupancy parameters. The FAA Technical Center examined 12 months of data during the period of September 2010 through August 2011 from Anchorage Oceanic and Offshore Airspace. 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.

14.3.5. The same and opposite direction occupancies were computed to be 0.0461 and 0.0216, respectively. These values represent the average occupancy across the busiest airways in the NOPAC route system.

14.3.6. More conservative lateral occupancy values were observed at the adjacent airway fixes PASRO and AKISU, located on routes A590 and R591, respectively. Airway A590 is a one-way route containing eastbound traffic. Airway R591 contains bi-directional traffic using flight level allocation rules. As noted in paragraph 3.5, airway A590 has the largest percent of ADS-C traffic in Anchorage Oceanic and Offshore Airspace. The opposite direction lateral occupancy at the adjacent PASRO / AKISU airway fixes was estimated to be 0.0654, which is approximately three times larger than the average opposite direction lateral occupancy, 0.0216.

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

14.4.1. As mentioned in paragraph 2.3, 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, described in section 8, are combined to estimate the lateral overlap probability.

14.4.2. In the past, aircraft lateral deviations have been modeled as Double-Double Exponential (DDE) random variables (Reference 5). A probability density function for the DDE distribution is given in Eq. (4) as:

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

14.4.3. The DDE density is a weighted sum of two Double Exponential densities, one often called the "core" density, and the other known as the "tail" density (Reference 5). 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.

14.4.4. The core density is determined by 4-NM / 95 percent containment. Reference 5 shows λ_1 can be estimated directly from the RNP value for the airspace. In this case, λ_1 is estimated to be 1.335-NM.

14.4.5. The tail density is determined by the frequency of the atypical lateral errors reported in the airspace. It has been shown using principles of differential calculus that the overlap probability can be approximately maximized by selecting a λ_2 equal to the designated separation minimum, in this case 30-NM. The contribution of the tail density is determined by α. The frequency of lateral errors described in Section 8 Table 11 gives the value for α as 7.20 x 10^{-5}.

14.4.6. The probability of lateral overlap is determined by self-convolving the density given in (4) with the parameter estimates given above. The resulting value for the probability of lateral overlap used in this safety assessment is 5.87 x 10^{-8}.

14.5. Table 16 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 Anchorage Oceanic and Offshore Airspace.

Table 16. Parameter Values for the Lateral Collision Risk Model for the 30-NM Lateral Separation Standard in Anchorage Oceanic and Offshore 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	17 knots	Estimated from ADS-C reports in traffic sample, Section 14.1
$\overline{\lvert V\rvert}$	Average absolute aircraft air speed	480 knots	Reference 8
$\overline{\lvert\dot{y}(30)\rvert}$	Average absolute relative cross track speed	48 knots	Section 14.2
$\overline{\lvert\dot{z}\rvert}$	Average absolute relative vertical speed of an aircraft pair that have lost all vertical	1.5 knots	Reference 8

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
	separation		
S_x	Length of longitudinal window used to calculate occupancy	120-NM	Reference 8
λ_x	Average aircraft length	0.0363-NM	Weighted average based on traffic sample, Section 13.1
λ_y	Average aircraft wing-span	0.0331-NM	Weighted average based on traffic sample, Section 13.1
λ_z	Average aircraft height with undercarriage retracted.	0.0101-NM	Weighted average based on traffic sample, Section 13.1
$P_z(0)$	Probability that two aircraft which are nominally at the same level are in vertical overlap.	0.538	Reference 8
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.	5.87×10^{-8}	Determined from the RNP requirement and the observed frequency of lateral errors in ZAN airspace, Section 14.4
$E_y(same)$	Same direction lateral occupancy	0.0461	Average value estimated from twelve month traffic movement sample, Section 14.3
$E_y(opp)$	Opposite direction lateral occupancy	0.0216	Average value estimated from twelve month traffic movement sample, Section 14.3

15. Parameters Used Only in Estimation of Longitudinal Risk

15.1. Assumed average ground speed of aircraft 1, V_1, and aircraft 2, V_2

15.1.1. The assumed average speed of aircraft 1, V_1, and aircraft 2, V_2,, is 480 knots as in reference 8. This is also a value used in the vertical collision risk model for Anchorage Oceanic and Offshore Airspace.

15.2. Average aircraft wingspan or length - λ_{xy}

15.2.1. The average aircraft wingspan or length, λ_{xy}, is taken to be the larger of either the average wingspan or length. This value, as provided in section 13, Table 15, is 0.0363-NM.

15.3. Scale parameter for the speed error distribution - λ_v

15.3.1. The speed error distribution is used to model variations in speed around the nominal speed. The speed error is modeled as in reference 6 which used a scale parameter, λ_v with a value of 5.82 knots. This value was based on a sample of 10,318 ADS reports during the years 1994 and 2000 (reference 6).

15.4. ADS-C report interval - T

15.4.1. Several ADS-C reporting rates have an effect on the longitudinal collision risk and are considered in this safety assessment. The required reporting rate specified in ICAO Doc 4444 (reference) for the use of the 30-NM longitudinal separation standard is 14 minutes. In addition to the 14 minute reporting rate, 9, 10, 11, 12, and 13 minute reporting rates are considered. A more frequent ADS-C reporting of position will typically yield a lower risk of collision.

15.5. Controller intervention buffer - τ

15.5.1. Tables 4 through 6 provide the components of the controller intervention buffer contained in reference 6. The safety assessment in this document utilizes empirical data for the CPDLC uplink data link portion of the controller intervention buffer. Table 17 contains the empirical distribution obtained from operations in Anchorage Oceanic and Offshore Airspace from September 2010 through August 2011. The maximum value a CPDLC uplink transit time was 362 seconds. The data in Table 17 show that more than 98 percent of the uplink CPDLC messages were delivered within 90 seconds.

Table 17. Anchorage Oceanic and Offshore Airspace Uplink CPDLC Transit Time Data, September 2010 – August 2011

Uplink Time (Seconds)	Count	Relative Frequency	Cumulative Frequency
0≤X<30	24,980	95.17%	95.17%
30≤X<60	689	2.62%	97.79%
60≤X<90	229	0.87%	98.67%
90≤X<120	251	0.96%	99.62%
120≤X<180	90	0.34%	99.97%
X≥180	9	0.03%	100.00%
Total	26,248	1	100.00%

15.6. Cross-track and along-track position error distributions

15.6.1. A double exponential distribution is used for the aircraft along-track and cross-track position errors. A mixture of GPS vs. non-GPS operations is needed to accurately model actual navigation performance. The actual navigation performance for GPS aircraft uses a scale parameter, $\lambda = \frac{k}{-\ln(0.5)}$, where k = 0.3. (See paragraph 5.10.4). Reference 9 also modeled the GPS aircraft cross-track and along-track position errors in this manner. The actual navigation performance for remaining non-GPS operations eligible for the 30-NM longitudinal separation is modeled with $k = 4$, which means 95 percent of the time operations are conducted within 4-NM of route centerline.

15.6.2. The mixtures of GPS vs. non-GPS operations considered in this safety assessment are the following:

- 100 percent GPS
- 100 percent non-GPS
- 50 percent GPS and 50 percent non-GPS
- 25 percent GPS and 75 percent non-GPS

15.6.3. The use of GPS in determining aircraft position produces highly accurate results. In turn, these accurate position estimates produce smaller lateral errors from course and lower across track velocities. Smaller lateral errors produce higher values of lateral overlap probability, thus increasing the risk of collision in the event that airplanes lose their assigned longitudinal separation. This “navigation paradox” – improvements in navigation in one dimension increase collision risk in another – is well known. Its presence in the application of 30-NM longitudinal separation minimum is found in the risk estimates.

15.7. Number of aircraft pairs per hour, *NP*

15.7.1. The number of aircraft pairs expected to have the 30-NM longitudinal separation standard applied per hour, NP, set equal to 1. The FAA Technical Center regularly examines the Ocean21 data archives to observe the application of the 50-NM longitudinal separation standard. The most recent examination for the time period of September 2010 through August 2011 yielded 438 aircraft pairs with the 50-NM longitudinal separation standard applied, or an average of 37 aircraft pairs per month. The 438 aircraft pairs observed in the archived data had a longitudinal separation greater than or equal to 50-NM and less than 80-NM. Given this observation, the NP value of 1 is accurate, as it covers time periods of higher volume when more eligible aircraft pairs are in the airspace.

15.8. Table of longitudinal collision risk parameters

15.8.1. Table 18 contains a summary of the longitudinal collision risk model parameters used in the safety assessment for the 30-NM longitudinal separation in Anchorage Oceanic and Offshore Airspace.

Table 18. Longitudinal Collision Risk Parameters for Anchorage Oceanic and Offshore Airspace

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
V_1	Assumed average ground speed of aircraft 1	480 knots	Reference 6
V_1	Assumed average ground speed of aircraft 2	480 knots	Reference 6
λ_{xy}	Average aircraft wingspan or length	0.0363-NM	Estimated from Anchorage traffic sample data, Section 13.1
λ	Scale parameter for speed error distribution	5.82 knots	Reference 6
T	ADS-C periodic report	Varies - 9, 10, 11, 12,	Reference 6 and 9

Parameter Symbol	Parameter Definition	Parameter Value	Source for Value
	rate	13, and 14 minutes considered	
τ	Controller intervention buffer.	3 cases (see Tables 4 – 6) with empirical data for ZAN CPDLC Uplink	Reference 6 and Ocean21 archived CPDLC data
NP	Number of aircraft pairs per hour	1	Estimate based on Ocean21 archived traffic data, Section 15.7

16. Estimation of Lateral Risk and Comparison to the TLS

16.1. Using the parameter values defined in section 14 and the lateral collision risk model stated in equation (1), the estimate of lateral collision risk for RNP 4 ADS-C aircraft operating in Anchorage Oceanic and Offshore Airspace with a 30-NM lateral separation standard is 3.35 x 10^{-9} fatal accidents per flight hour (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.

17. Estimation of Longitudinal Risk and Comparison to the TLS

17.1. Using the parameter values defined in section 15 and the longitudinal collision risk model stated in equation (2), the estimate of longitudinal collision risk for ADS-C aircraft operating in Anchorage Oceanic and Offshore Airspace with a 30-NM longitudinal separation standard varies with the mixture of GPS vs non-GPS operations and ADS-C reporting rate as shown in Figure 9.

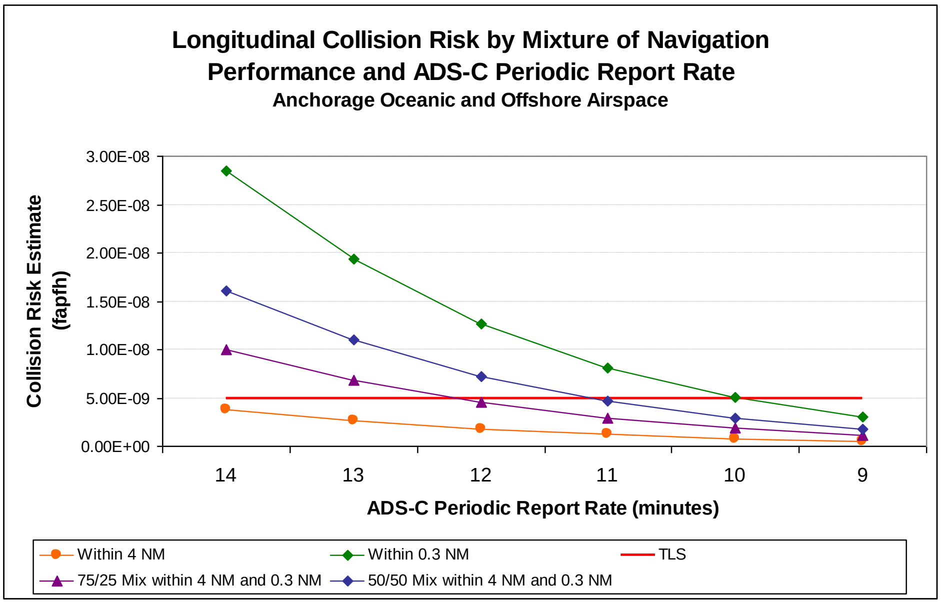

Figure 9. Longitudinal Collision Risk by ADS-C Report Rate and Mixture of Navigation Performance

17.2. The data shown in Figure 9 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 orange line in Figure 9. The mixture of GPS vs non-GPS used in reference 9 is approximately 50 percent GPS and 50 percent non-GPS. Current data show that the proportion of RNP 4 operations in Anchorage

Oceanic and Offshore Airspace is approximately 25 percent as given in Table 1. The purple line with the label “75/25 Mix within 4 NM and 0.3 NM” in Figure 9 shows the risk estimates when 25 percent of operations use GPS for navigation and the remaining 75 percent meet the required navigation performance. However, it is likely that more than 25 percent of operations use GPS for navigation given that 75 percent of operations were observed using ADS-C for reporting position (paragraph 3.9). Therefore, the blue line with the label, “50/50 within 4 NM and 0.3 NM”, is the choice for this safety assessment. This 50-50 mixture follows that used in reference 9 for the adjacent Fukuoka oceanic airspace.

17.3. Assuming that 50 percent of operations have an observed navigation performance within 0.3 NM of route centerline, and the remaining 50 percent have the required navigation performance within 4 NM of route centerline, the longitudinal collision risk estimate is 4.69 x 10^{-9} fapfh with an 11-minute ADS-C periodic report rate. Although this value is lower than the agreed TLS, it does not allow much room for growth and expansion. Figure 9 suggests that the risk estimate will increase with the assumed proportion of operations having the observed navigation performance within 0.3 NM of route centerline. Therefore, the results from this safety assessment show that an ADS-C periodic report rate of 10 minutes provide an acceptable estimate of collision risk of 2.92 x 10^{-9} fapfh for the implementation of the 30-NM longitudinal separation standard in Anchorage Oceanic and Offshore 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 x 10^{-9} fapfh due to the loss of planned longitudinal separation.

18. Post-implementation monitoring

18.1. As noted previously, the FAA Technical Center acts as both an EMA and RMA, known as the PARMO, for Anchorage Oceanic and Offshore Airspace. In the Asia and Pacific region, established EMAs and RMAs report to the RASMAG which, in turn, reports to the APANPIRG. The safety monitoring reports, both horizontal and vertical, cover the current 12-month period and are produced twice a year. In order to produce the required safety monitoring reports, an EMA/RMA must collect appropriate traffic data and event reports from the airspace.

18.2. To fulfill the APANPIRG requirements, the PARMO currently receives reports of large height deviations (LHDs) and GNEs, and time (longitudinal) errors from the Anchorage ARTCC. These reports are sent to the FAA Technical Center using the PARMO monthly report form or through FAA Order 7110.82D.

18.3. The results of the post-implementation monitoring activities related to the implementation of the 30-NM lateral and 30-NM longitudinal separation minima in Anchorage Oceanic and Offshore Airspace will be provided in the horizontal safety monitoring report submitted to RASMAG twice a year. The post-implementation monitoring activities will include a current estimate of the lateral and longitudinal collision risk based on the most recent reported events and traffic data. Additional post-implementation monitoring items include;

- Data link performance monitoring results,
- Summary of recent reported data link outages,
- Summary of overdue ADS-C reports,
- Summary of reported GNE and time error events,
- Comparison of RNP filing status against RNP approval database,

- Updated collision risk model parameters such as lateral occupancy values, aircraft size, and aircraft speeds, and
- Analyses of the actual application of the reduced horizontal separation minima, e.g. number of aircraft pairs, initial and final separation distance (longitudinal).

19. Conclusions

19.1. This report examined the risk of collision for the application of reduced lateral and reduced longitudinal separation minima to 30-NM in Anchorage Oceanic and Offshore Airspace. In combination with data collected from the area of application, the ICAO-endorsed collision risk methodology was used to prepare an estimate of the collision risk upon introduction 30-NM lateral and longitudinal separation minima. Those risk estimates were compared to the Target Level of Safety (TLS) of 5×10^{-9} fapfh due, separately, to the loss of 30-NM lateral and 30-NM longitudinal separation, following the guidelines for implementing these separation minima in international airspace and formerly contained within ICAO Annex 11.

19.2. Using the ICAO recommended collision risk model, the estimate of lateral collision risk for RNP 4, ADS-C aircraft operating in Anchorage Oceanic and Offshore Airspace with a 30-NM lateral separation minimum is forecast to be 3.35×10^{-9} fapfh. This value is below the ICAO-endorsed TLS value applicable to judging the safety of the lateral separation standard in international airspaces, 5.0×10^{-9} fapfh due to the loss of planned lateral separation. More conservative estimates of risk can be obtained from the use of actual parameter estimates from the busiest areas of the airspace instead of average parameter values, although it is not recommended practice to compute risk in this manner. For example, the use of lateral occupancy values from the busiest airways in the airspace, as opposed to lateral occupancy values averaged across the airspace, yield more conservative risk estimates. Keeping all the other parameters the same, the average lateral opposite direction occupancy should be 0.056 or lower, to achieve a risk estimate below the agreed TLS.

19.3. Using the ICAO recommended collision risk model, the estimate of longitudinal collision risk for RNP 4 ADS-C aircraft operating in Anchorage Oceanic and Offshore Airspace with a 30-NM longitudinal separation minimum varies with combinations of aircraft exhibited navigational performance and ADS-C reporting rate. ADS-C reporting rates have a primary effect on the longitudinal collision risk and are manipulated through the ADS-C contract established between the ground and each aircraft. The achieved lateral navigational performance of the population of aircraft to which the separation minimum is to be applied also has an effect. The study looked specifically at the interaction between the composition of the navigational performance of the population and the ADS-C periodic update rates. Assuming 50 percent of operations utilize GPS for navigation with an achieved accuracy better than RNP 4, the remaining 50 percent are non-GPS but exactly achieve RNP 4, and a 11-minute ADS-C periodic report rate, the longitudinal collision risk estimate is 4.69×10^{-9} fapfh. Although this value is lower than the agreed TLS, it does not allow much room for future growth and expansion.

19.4. . As is seen in Figure 9, the collision risk estimate will increase with a greater proportion of operations using GPS with an achieved accuracy of better than RNP 4. Therefore, the results from this safety assessment show that an ADS-C periodic report rate of 10 minutes produces an estimate of collision risk of 2.92×10^{-9} fapfh for the implementation of the 30-NM longitudinal separation minimum in Anchorage Oceanic and Offshore 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.

19.5. These prospective analyses depend on estimates derived from the current operations in the airspace of application along with conservative projections of various parameters likely to either contain future operations or to be reasonable approximations. Since they are forecasts, there is some chance that the actual operations after implementation will vary from the forecast. To ensure that the post-implementation system will remain below the TLS, it is recommended that the longitudinal separation minimum of 30 NM be implemented with a 10-minute ADS-C periodic rate. It is noteworthy that his rate is consistent with that used by the JCAB for 30 NM the longitudinal separation minimum in the adjacent Fukuoka FIR.

19.6. This document also provided the planned post-implementation monitoring activities to be conducted by the FAA Technical Center and the Anchorage ARTCC associated with the continued safe-use of the reduced horizontal separation minima.

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Appendix A
Operations Eligible for the 30-NM Lateral and 30-NM Longitudinal Separation Standards in Anchorage Oceanic and Offshore Airspace (September 2010 – August 2011)
Utilize ADS-C and File RNP 4

Operator ICAO Identifier	Operator Name	State of Operator	Aircraft Type	Count	Proportion in Sample
AMX	Aerovias De Mexico, S.A. DE C.V.	Mexico	B772	7	0.05%
CKK	China Cargo Airlines LTD	China	B744	68	0.51%
COA	Continental Air Lines, INC.	United States	B772	630	4.76%
CPA	Cathay Pacific Airways, LTD.	Hong Kong, China	A343	24	0.18%
CPA	Cathay Pacific Airways, LTD.	Hong Kong, China	B744	3,015	22.79%
CPA	Cathay Pacific Airways, LTD.	Hong Kong, China	B773	1,028	7.77%
DAL	Delta Air Lines, INC.	United States	B772	895	6.77%
GWL	Great Wall Airlines CO., LTD.	China	B744	176	1.33%
IGA	NA	NA	B737	3	0.02%
IGA	NA	NA	GLF4	15	0.11%
IGA	NA	NA	GLF5	52	0.39%
KAL	Korean Air Lines CO., LTD.	Republic of Korea	A332	73	0.55%
KAL	Korean Air Lines CO., LTD.	Republic of Korea	A333	2	0.02%
KAL	Korean Air Lines CO., LTD.	Republic of Korea	A388	9	0.07%
KAL	Korean Air Lines CO., LTD.	Republic of Korea	B744	577	4.36%
KAL	Korean Air Lines CO., LTD.	Republic of Korea	B772	1,285	9.71%
KAL	Korean Air Lines CO., LTD.	Republic of Korea	B773	374	2.83%
RCH	Air Mobility Command (AMC)	United States	C17	51	0.39%
RCH	Air Mobility Command (AMC)	United States	C5	19	0.14%
RCH	Air Mobility Command (AMC)	United States	K35R	13	0.10%
SIA	Singapore Airlines, LTD.	Singapore	A388	1	0.01%
SIA	Singapore Airlines, LTD.	Singapore	B744	40	0.30%
SIA	Singapore Airlines, LTD.	Singapore	B773	44	0.33%
SOO	Southern Air, Inc. (Columbus, OH)	United States	B772	1	0.01%
SQC	Singapore Airlines Cargo PTE, LTD.	Singapore	B744	273	2.06%
STATE	NA	NA	B737	28	0.21%
STATE	NA	NA	B742	2	0.02%
STATE	NA	NA	B752	7	0.05%
STATE	NA	NA	C135	5	0.04%
STATE	NA	NA	C17	11	0.08%
STATE	NA	NA	C5	3	0.02%
STATE	NA	NA	K35R	99	0.75%
UAL	United Airlines, INC.	United States	B744	987	7.46%
UAL	United Airlines, INC.	United States	B772	1,706	12.90%

Operator ICAO Identifier	Operator Name	State of Operator	Aircraft Type	Count	Proportion in Sample
UPS	United Parcel Service CO., (Louisville, KY)	United States	B744	739	5.59%
UPS	United Parcel Service CO., (Louisville, KY)	United States	MD11	967	7.31%
TOTAL				**13,229**	

Appendix B
Observed RCP and RSP for Anchorage Oceanic and Offshore Airspace

B. Observed Data Link Performance

C.1. This section provides a summary of the observed performance of the operational data link system in Anchorage Oceanic and Offshore Airspace. The purpose is to compare the measured performance obtained from analysis of the operational data to the criteria specified in the GOLD (reference 9).

C.2. The performance data observed from the CPDLC system is assessed against the RCP240 specification when sent via satellite or VHF data link and against the RCP400 specification when sent via HF data link. The latency performance data observed from the Automatic Dependent Surveillance - Contract (ADS-C) system is measured against the RSP180 specification when sent via satellite or VHF data link and the RSP400 specification when sent via HF data link. The purpose of this analysis is to determine whether safety objectives which rely on the communications infrastructure can be met by the aircraft and ground systems. The sample period of April 2011 through September 2011 was examined for Anchorage Oceanic and Offshore Airspace.

C.3. Figure B-1 presents the ADS-C latency performance by media type (satellite, VHF, and HF data link) for Anchorage Oceanic and Offshore Airspace. The chart key provides the number of messages included for each media type. The RSP180 criteria, 95 percent of the messages delivered by 90 seconds and 99.9 percent of the messages delivered by 180 seconds, are drawn in Figure B-1. It is noted that the HF data link performance should be compared against the RSP400 criteria, but is included in Figure B-1 for convenience.

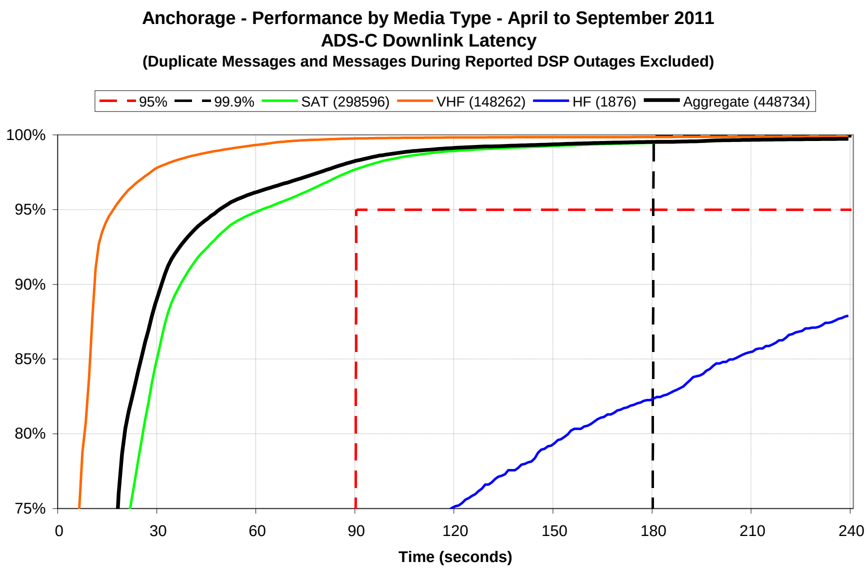

Figure B-1. ADS-C Downlink Latency by Media Type – April through September 2011

C.4. Figures B-2, B-3, and B-4 present the ACP, ACTP, and ADS-C performance, respectively, for messages delivered by satellite data link by month within Anchorage Oceanic and Offshore Airspace. Figure B-5 shows the ADS-C downlink latency performance by month for messages delivered via HF data link within Anchorage Oceanic and Offshore Airspace.

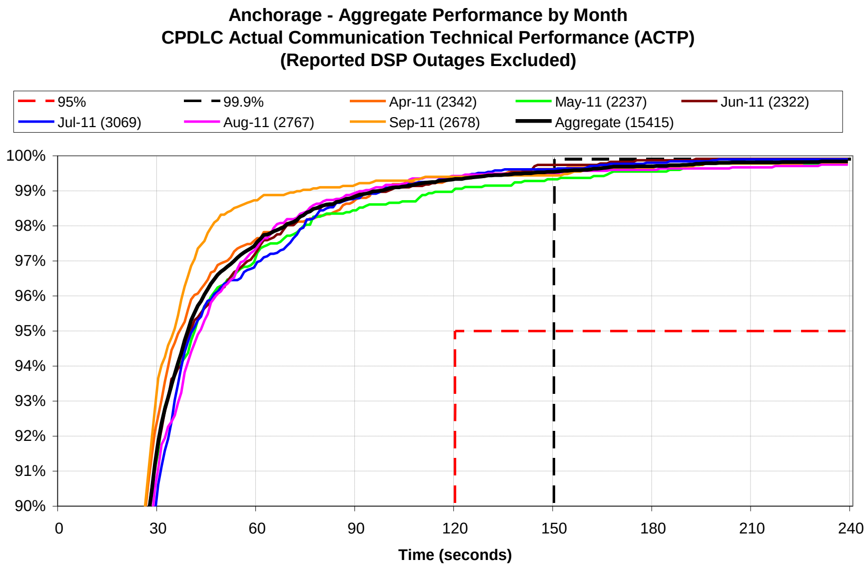

Figure B-2. CPDLC ACTP for Messages Delivered via Satellite Data Link by Month – April through September 2011

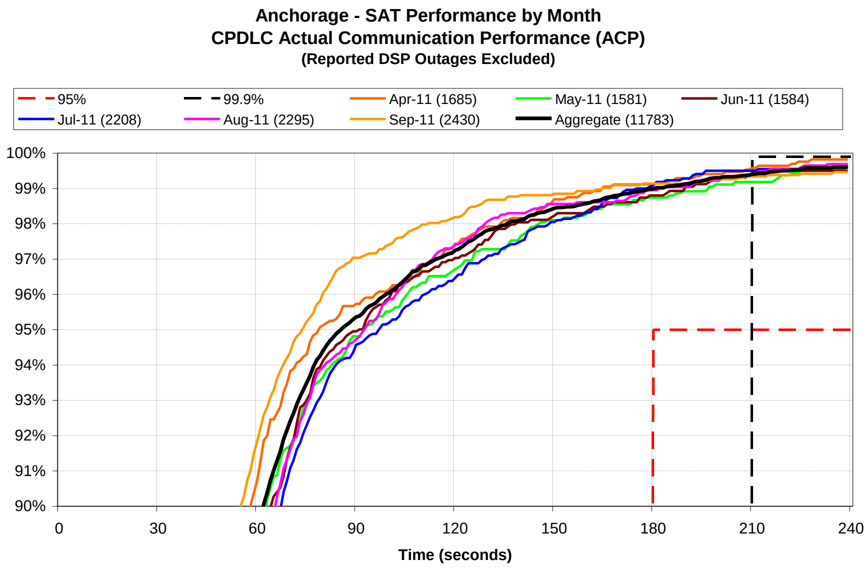

Figure B-3. CPDLC ACP for Messages Delivered via Satellite Data Link by Month – April through September 2011

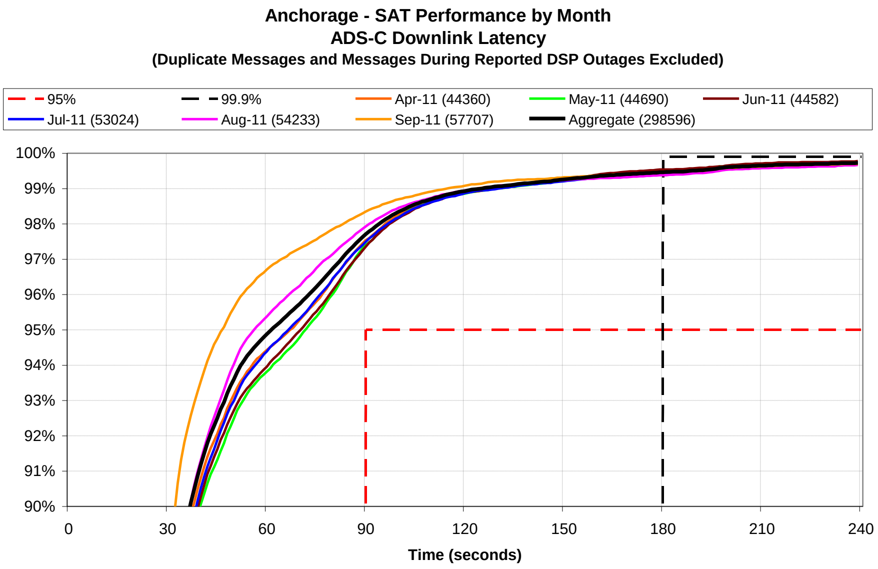

Figure B-4. ADS-C Downlink Latency for Reports Delivered via Satellite Data Link by Month – April through September 2011

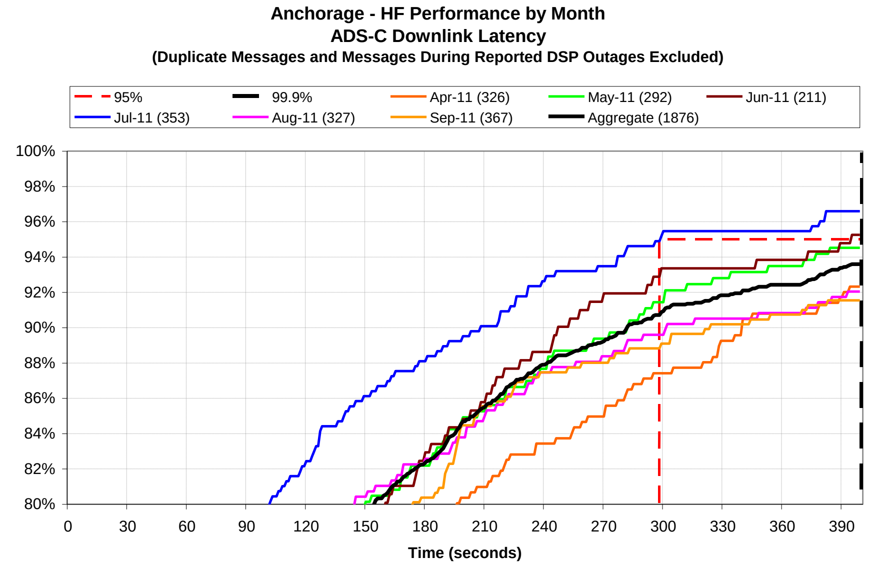

Figure B-5. ADS-C Downlink Latency for Reports Delivered via HF Data Link by Month – April through September 2011

C.5. Figures B-2 and B-3 show that the aggregate ACP, and ACTP performance for the messages delivered via satellite data link meet the 95 percent criterion for RCP240. Figure B-4 shows that the

95 percent RSP180 criterion was met for ADS-C reports sent via satellite data link over the six month period.

C.6. Figure B-5 shows that the 95 percent RSP400 criterion for ADS-C reports sent via HF data link was met in July 2011 only, while the observed HF data link performance during the remaining five months did not meet the 95 percent criterion for RSP400.

C.7. Table B-1 provides the observed ACP, ACTP, PORT and ADS-C performance at the appropriate 95 and 99.9 target levels for the top 90 percent of operators in terms of message counts. These data include messages sent via satellite data link only over the time period of July through September 2011. The values that appear in **blue** indicate that the 99.9 percent target level was attained. The values that appear in **red** indicate that the 95 percent criteria were not met. The operator information has been de-identified in the table.

Table B-1. Summary of Data Link Performance for Top 90% of ADS-C and CPDLC Messages by Operator

Operator Code	Count of SAT ADS-C	% of Total SAT ADS-C	ADS-C 95%	ADS-C 99.9%	Count of SAT CPDLC	% of Total SAT CPDLC	ACTP 95%	ACTP 99.9%	ACP 95%	ACP 99.9%	PORT 95%
Q	23,796	14.42%	97.94%	99.58%	962	13.88%	99.48%	99.69%	99.48%	**99.90%**	96.15%
D	15,301	9.28%	97.09%	99.49%	390	5.63%	99.74%	99.74%	99.74%	**100.0%**	96.41%
Y	15,019	9.10%	96.10%	97.74%	258	3.72%	97.67%	97.67%	96.51%	97.29%	94.96%
L	14,997	9.09%	99.08%	99.79%	569	8.21%	99.65%	99.65%	98.95%	99.30%	**93.85%**
A	10,577	6.41%	95.51%	99.22%	430	6.20%	99.77%	99.77%	98.84%	99.77%	**92.79%**
H	10,561	6.40%	99.35%	99.81%	630	9.09%	99.68%	99.84%	99.37%	**100.0%**	98.25%
S	10,272	6.23%	97.54%	99.78%	542	7.82%	99.45%	**100.0%**	98.89%	99.08%	94.65%
J	8,716	5.28%	99.86%	**99.92%**	484	6.98%	100.0%	**100.0%**	100.0%	**100.0%**	98.97%
F	8,489	5.15%	97.89%	99.81%	544	7.85%	99.26%	99.63%	99.63%	99.63%	98.35%
G	7,584	4.60%	99.66%	**99.93%**	453	6.53%	99.78%	99.78%	99.34%	99.34%	99.12%
R	6,156	3.73%	95.74%	99.27%	277	4.00%	98.92%	99.28%	98.92%	99.28%	96.03%
P	4,878	2.96%	97.81%	99.59%	258	3.72%	98.84%	99.22%	97.29%	98.06%	**90.31%**
T	4,738	2.87%	98.65%	99.66%	237	3.42%	98.73%	99.16%	99.16%	99.16%	98.31%
QQQ	4,546	2.76%	99.43%	99.65%	215	3.10%	100.0%	**100.0%**	100.0%	**100.0%**	99.53%
M	3,796	2.30%	96.94%	99.24%	149	2.15%	100.0%	**100.0%**	96.64%	96.64%	**93.29%**

C.8. Table B-1 shows the data link performance for 15 commercial operators. The aggregate data link performance for the messages from each of the 15 operators listed in Table B-1 meet the ADS-C downlink latency 95 percent criterion for RSP180. In addition, the aggregate data link performance for the CPDLC messages from the 15 operators listed in Table B-1 meet the 95 percent criterion for RCP240 for ACP and ACTP. The data show that the aggregate message sets from several of the operators listed in Table B-1 meet the 99.9 percent criteria for ACP, ACTP and ADS-C latency. The aggregate CPDLC message sets from four of the operators listed in Table B-1 do not meet the 95 percent criterion for PORT within 60 seconds.

Appendix C
Relative Along-Track Speed of Two Aircraft As They Pass on Parallel Tracks

C.1. Aircraft operations on parallel tracks are independent of application of Mach number technique or any other actions by ATC to regulate the relative speed between aircraft. As a result, the relative speed between a typical pair of co-altitude aircraft on adjacent tracks reflects the range of speeds of individual aircraft in the airspace. The Technical Center assembled the reported ground speeds, obtained from ADS-C basic reports, for 17,227 flights in Anchorage Oceanic and Offshore Airspace for the period September 2010 through August 2011, with the results shown in Table C-1 below.

Table C-1. Empirical Distribution of Aircraft Reported Ground Speeds in Anchorage Oceanic and Offshore Airspace

Average Ground Speed (knots)	Number of Flights	Proportion
380	3	0.000174
385	0	0.000000
390	0	0.000000
395	1	0.000058
400	0	0.000000
405	3	0.000174
410	8	0.000464
415	18	0.001045
420	19	0.001103
425	34	0.001974
430	69	0.004005
435	98	0.005689
440	175	0.010158
445	232	0.013467
450	354	0.020549
455	405	0.023510
460	522	0.030301
465	750	0.043536
470	964	0.055959
475	1087	0.063099
480	1170	0.067917
485	1219	0.070761
490	1189	0.069020
495	1160	0.067336
500	1082	0.062808
505	965	0.056017
510	892	0.051779
515	750	0.043536
520	654	0.037964
525	565	0.032797
530	503	0.029198
535	410	0.023800
540	350	0.020317
545	274	0.015905
550	248	0.014396
555	198	0.011494
560	184	0.010681

Average Ground Speed (knots)	Number of Flights	Proportion
565	156	0.009056
570	137	0.007953
575	92	0.005340
580	68	0.003947
585	51	0.002960
590	25	0.001451
595	25	0.001451
600	22	0.001277
605	17	0.000987
610	13	0.000755
615	18	0.001045
620	17	0.000987
625	7	0.000406
630	6	0.000348
635	9	0.000522
640	7	0.000406
645	0	0.000000
650	2	0.000116
TOTAL	17,227	