



International Civil Aviation Organization  
**ICAO** Twenty-Seventh Meeting of the Regional Airspace Safety  
Monitoring Advisory Group (RASMAG/27)

Video Teleconference, 22 – 25 August 2022

**Agenda Item 3: Reports from Asia/Pacific RMAs and EMAs**

**PARMO HORIZONTAL SAFETY MONITORING REPORT 2021**

(Presented by United States/PARMO)

**SUMMARY**

This paper presents the horizontal safety monitoring report from the Pacific Approvals Registry and Monitoring Organization (PARMO) for the period 1 January to 31 December 2021. This report contains a summary of large longitudinal errors and large lateral deviations received by the PARMO for that period and the related performance monitoring activities for the Anchorage, Auckland, Nadi, Oakland, and Tahiti Flight Information Regions (FIRs).

**1. INTRODUCTION**

1.1 The Pacific Approvals Registry and Monitoring Organization (PARMO), serves as the En-route Monitoring Agency (EMA) for the Anchorage, Auckland, Nadi, Oakland, and Tahiti Flight Information Regions (FIRs). The report presented in this paper fulfills the ICAO emphasis on safety management systems; such reporting for international airspace is a component of safety management systems.

1.2 This working paper contains the PARMO horizontal safety monitoring report for the time period 1 January to 31 December 2021. This paper contains a summary of large lateral deviation (LLD) and large longitudinal error (LLE) reports received by the PARMO during the reporting period.

**2. DISCUSSION**

2.1 **Attachment A** contains the PARMO Horizontal Safety Monitoring Report for January to December 2021.

Executive Summary

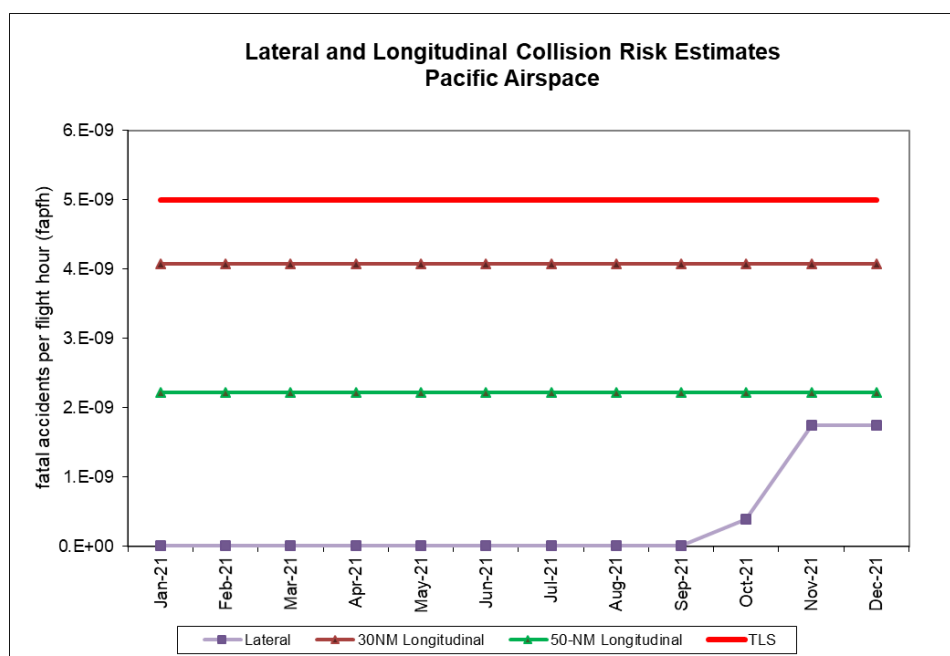
2.2 **Table 1** provides the Pacific airspace horizontal risk estimates. **Figure 1** presents the lateral and longitudinal collision risk estimate trends for Pacific airspace during the period January 2021 to December 2021.

<b>Pacific Airspace – estimated annual flying hours = 1,176,737.3 hours</b> (note: estimated hours based on Dec 2021 traffic sample data)			
<b>Source of Risk</b>	<b>Risk Estimation</b>	<b>TLS</b>	<b>Remarks</b>
RASMAG 25 Lateral Risk	$0.09 \times 10^{-9}$	$5.0 \times 10^{-9}$	Below TLS
RASMAG 25 30NM Longitudinal Risk	$4.08 \times 10^{-9}$	$5.0 \times 10^{-9}$	Below TLS
RASMAG 25 50NM Longitudinal Risk	$2.22 \times 10^{-9}$	$5.0 \times 10^{-9}$	Below TLS

<b>Pacific Airspace – estimated annual flying hours = 1,176,737.3 hours</b> <i>(note: estimated hours based on Dec 2021 traffic sample data)</i>			
<b>Source of Risk</b>	<b>Risk Estimation</b>	<b>TLS</b>	<b>Remarks</b>
Lateral Risk	$1.74 \times 10^{-9}$	$5.0 \times 10^{-9}$	<b>Below TLS</b>
30NM Longitudinal Risk	$4.08 \times 10^{-9}$	$5.0 \times 10^{-9}$	<b>Below TLS</b>
50NM Longitudinal Risk	$2.22 \times 10^{-9}$	$5.0 \times 10^{-9}$	<b>Below TLS</b>

**Table 1:** Pacific Airspace Horizontal Risk Estimates

2.3 The longitudinal monitoring process was applied to the traffic data from the Anchorage Oceanic FIR. There were 2,247 longitudinal aircraft pairs observed on same identical routes and 165 longitudinal aircraft pairs observed on crossing routes in December 2021. The longitudinal monitoring process yields a longitudinal collision risk estimate of  $0.004 \times 10^{-9}$  fapfh.



**Figure 1:** Pacific Airspace Horizontal Risk Estimates

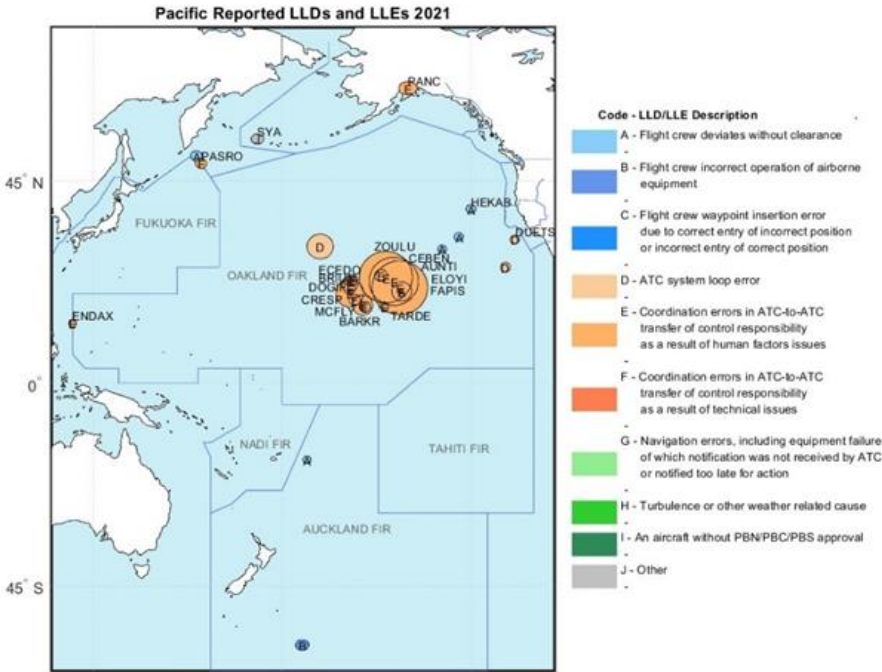
2.4 **Table 2** contains a summary of Large Lateral Deviations (LLD) and Large Longitudinal Errors (LLE) received by PARMO for Pacific airspace.

<b>Code</b>	<b>Deviation Description</b>	<b>No.</b>
A	Flight crew deviates without ATC clearance in the horizontal dimension	6
B	Flight crew incorrect operation or interpretation of airborne equipment	1
C	Flight crew waypoint insertion error, due to correct entry of incorrect position or incorrect entry of correct position	0
D	ATC system loop error	3
E	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of human factors issues	100
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues	0
G	Navigation errors due to airborne equipment failure leading to a deviation in the horizontal dimension of which notification was not received by ATC or notified too late for action	0
H	Turbulence or other weather related causes (other than approved) leading to a deviation in the horizontal dimension;	0
I	An aircraft was provided with reduced horizontal separation minima	0

Code	Deviation Description	No.
	but did not meet the RNP/RSP/RCP specification	
J	Others	1
Total		111

**Table 2:** Summary of Pacific Airspace LLD and LLE Reports

2.5 **Figure 2** provides the geographic location of risk bearing LLE and LLD reports within Pacific Airspace during the assessment period.



**Figure 2:** Locations of reported LLDs and LLEs – Calendar Year 2021

2.6 Mitigations for the high number of reported category E occurrences between Honolulu Control Facility (HCF) and Oakland center have been developed. A summary of the mitigations and planned automation system upgrade is provided in the attachment to this paper.

**3. ACTION BY THE MEETING**

- 3.1 The meeting is invited to:
- a) note the information contained in this paper; and
  - b) discuss any relevant matters as appropriate.

.....

## SAFETY REVIEW OF THE APPLICATION OF REDUCED HORIZONTAL SEPARATION MINIMA IN PACIFIC AIRSPACE January 2021 TO December 2021

Prepared by  
Pacific Approvals and Registry Monitoring Organization (PARMO) – August 2022  
(An ICAO APANPIRG approved Enroute Monitoring Agency)

### 1. Introduction

1.1 This report provides a safety review of the application of reduced horizontal separation minima in Pacific airspace. Specifically, this report utilizes data collected for the Anchorage, Auckland, Nadi, Oakland and Tahiti Flight Information Regions (FIRs).

### 2. Data Sources

2.1 **Traffic Sample Data (TSD).** A TSD covering the month of December 2021 for aircraft operations in the Anchorage, Auckland, Nadi, and Oakland FIRs was used as required by ICAO Regional agreement. **Table 1** indicates all FIRs have submitted a TSD to the PARMO.

**Table 1:** December 2021 TSD Submitted to PARMO

FIR	December 2021 TSD Submitted to PARMO
Anchorage	X
Auckland	X
Nadi	X
Oakland	X
Tahiti	X

2.2 **Large Lateral Deviations (LLDs) and Large Longitudinal Errors (LLEs).** A cumulative 12-month data set of LLD and LLE reports was used, covering January to December 2021. **Table 2** indicates those FIRs which submitted LLD and LLE reports including nil reports.

**Table 2:** Summary of LLD and LLE Reports submitted by FIRs

	Anchorage	Auckland	Nadi	Oakland	Tahiti
Jan 2021	X	X	X	X	X
Feb 2021	X	X	X	X	X
Mar 2021	X	X	X	X	X
Apr 2021	X	X	X	X	X
May 2021	X	X	X	X	X
Jun 2021	X	X	X	X	X
Jul 2021	X	X	X	X	X
Aug 2021	X	X	X	X	X
Sep 2021	X	X	X	X	X
Oct 2021	X	X	X	X	X
Nov 2021	X	X	X	X	X

	Anchorage	Auckland	Nadi	Oakland	Tahiti
Dec 2021	X	X	X	X	X

### 3. Summary of LLD and LLE Occurrences in Pacific Airspace

3.1 There were thirteen LLDs and ninety-eight LLEs reported to the PARMO during calendar year 2021. **Table 3** provides the number of reported LLDs and LLEs by month for all 111 reports.

**Table 3:** Summary of reported LLDs and LLEs for Pacific airspace – 2021

Month	No. of Reported LLDs and LLEs	Duration (min)	Number of tracks crossed w/o clearance
<b>2021</b>			
January	11	0	0
February	15	0	1
March	11	0	0
April	12	0	0
May	12	0	0
June	12	0	0
July	10	0	0
August	9	0	0
September	8	0	0
October	4	59	0
November	2	5	0
December	5	0	1
<b>Total</b>	<b>111</b>	<b>64</b>	<b>2</b>

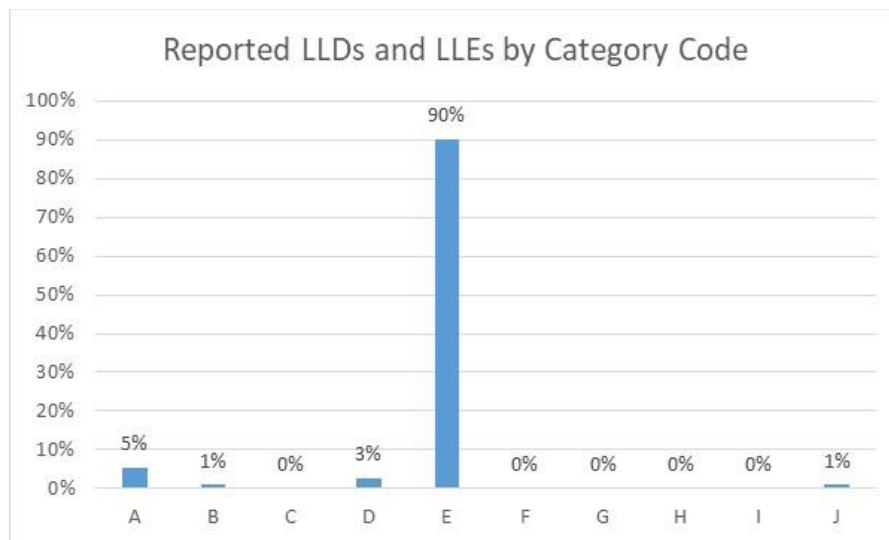
3.2 From the 111 reported occurrences, there were thirty-nine reported LLDs/LLEs that did not involve aircraft operations eligible for reduced separations. **Table 4** summarizes the number of reported LLDs and LLEs by category code from 1 January 2021 to 31 December 2021 inclusive for Pacific airspace.

3.3 **Table 5** summarizes all reported LLDs and LLEs by month and category. **Figure 1** shows relative proportion of all reported LLDs and LLEs by category code.

**Table 4:** Summary of reported LLDs and LLEs by category – 2021

Code	Deviation Description	No.
A	Flight crew deviates without ATC Clearance	6
B	Flight crew incorrect operation or interpretation of airborne equipment	1
C	Flight crew waypoint insertion error, due to correct entry of incorrect position or incorrect entry of correct position	0
D	ATC system loop error	3
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility due to human factor issues	100
F	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility due to technical issues	0
G	Navigation errors, including equipment failure of which notification was not received by ATC or notified too late for action	0
H	Turbulence or other weather related causes	0
I	An aircraft without PBN approval	0
J	Other	1
	<b>Total</b>	<b>111</b>

3.4 **Figure 2** provides a chart with the locations of the LLD and LLE reports. This graph also shows the LLD/LLE categories. The size of the plotted circle indicates the relative duration at that location compared to other plotted on the chart.



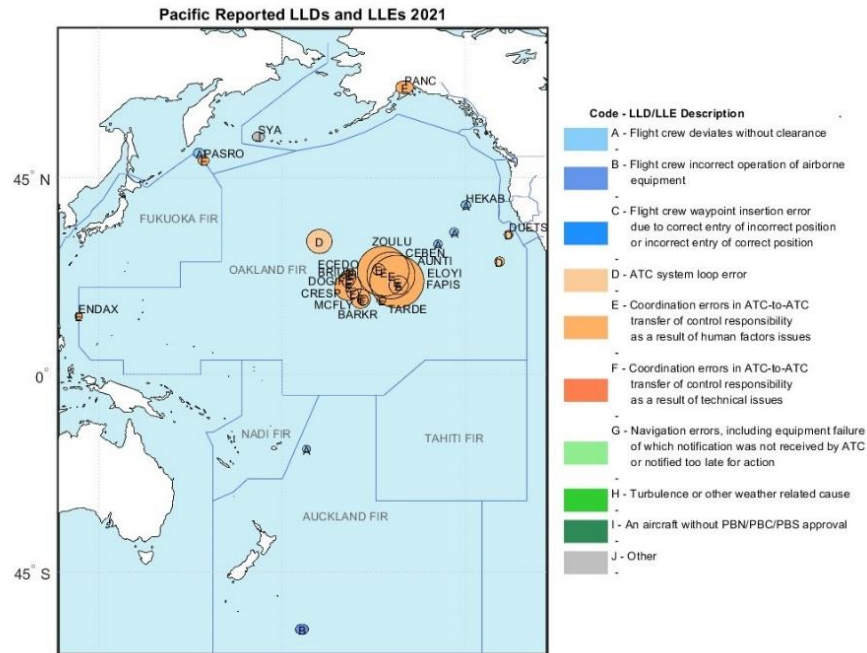
**Figure 1:** All Reported LLDs and LLEs by Category Code

3.5 Due to the variety of lateral separation standards available in Pacific airspace, it is necessary to examine each reported LLD to determine the eligible lateral separation standard(s) for the aircraft involved. It is not necessary that a lateral separation minimum been applied during the time of the occurrence. To determine eligibility for reduced separations, the filed required navigation performance (RNP), Required Communication Performance (RCP), and Required Surveillance Performance (RSP) specifications are examined. This practice, of analyzing reported LLD and LLE events by eligibility for reduced separation standards is a practice applied for risk estimates in other airspace such as the North Atlantic. This process is unique to horizontal risk estimation where there are a variety of performance-based separation minima available.

3.6 **Table 5** provides the number of reported LLDs and LLEs by month and category code. This table shows that category E reports is the top contributor to the number of reports. This result is similar to that observed in calendar years 2019 and 2020.

**Table 5:** Summary of LLD and LLE Reports submitted by FIRs

LLD and LLE Category Codes						
	A	B	D	E	J	Totals
Jan-21	0	0	0	11	0	11
Feb-21	1	0	0	14	0	15
Mar-21	2	1	0	8	0	11
Apr-21	1	0	0	11	0	12
May-21	0	0	0	12	0	12
Jun-21	1	0	0	11	0	12
Jul-21	1	0	0	9	0	10
Aug-21	0	0	0	9	0	9
Sep-21	0	0	0	8	0	8
Oct-21	0	0	1	3	0	4
Nov-21	0	0	1	1	0	2
Dec-21	0	0	1	3	1	5
<b>Totals</b>	<b>6</b>	<b>1</b>	<b>3</b>	<b>10</b>	<b>1</b>	<b>111</b>



**Figure 2:** Locations of reported LLDs and LLEs – Calendar Year 2021

### 3.7 Trends Observed in Reported Large Lateral Deviations (LLDs)

3.8 **Table 6** shows the trends in the number of reported LLDs by category for 2018 through 2021. The LLD category descriptions are provided in Table 4. There were thirteen reported LLDs for calendar year 2021. This is a slight increase in the overall number of reported LLDs received by PARMO compared to calendar year 2020. **Figure 3** shows the trend data in chart format for the categories related to aircrews. **Figure 4** shows the trend data for the categories related to ATC.

3.9 These data show a trend in category A LLDs for aircrews deviating without ATC clearance. In 2021, three of the six reported category A LLDs have indicated that weather (category H) was a secondary causal factor.

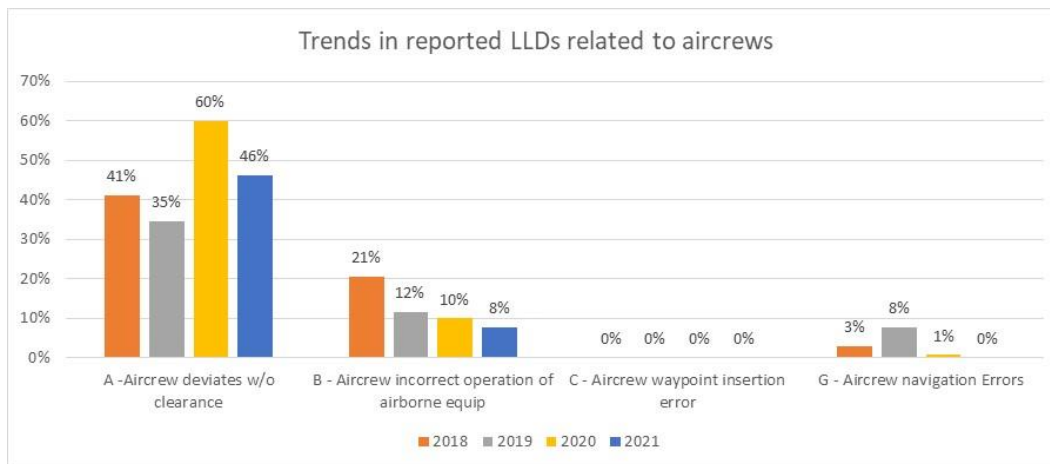
3.10 These data also show a slight change in the trend for category E LLDs, errors in ATC-to-ATC coordination, from 2018 - 2021. **Figure 5a** shows the locations of all reported LLDs by category in Pacific airspace, including those reports with deviation magnitudes not large enough to affect the calculated lateral risk. **Figure 5b** shows the locations of the reported LLDs with deviation magnitudes large enough to contribute towards the risk estimate. There were four LLD reports with deviation magnitudes large enough to affect the calculation of lateral risk. The Lateral Infringement Distance (LID) is used to determine contributions towards the calculation of lateral risk and is described later in this report.

3.11 The largest contributions to the calculated lateral risk are from category D LLD reports. There were two LLD reports that together, included 64 minutes of unprotected time in the airspace. One of

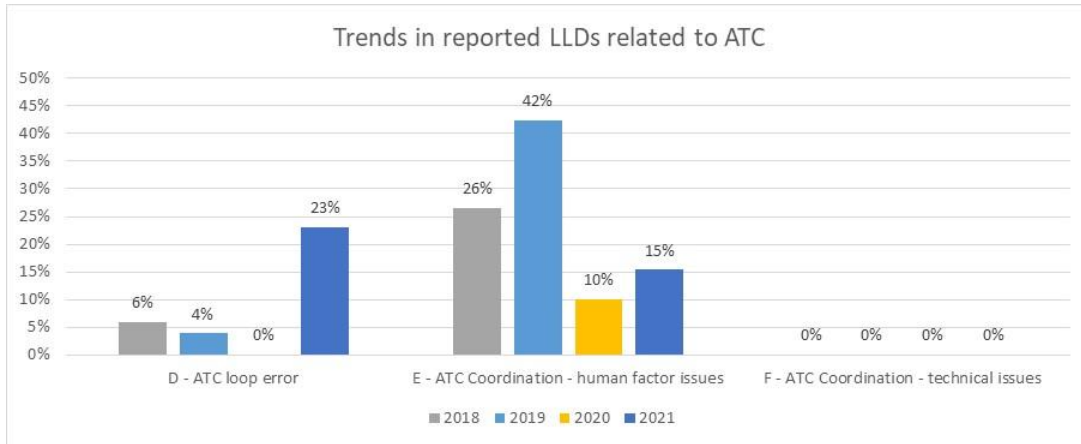
these LLD reports occurred in October 2021. This occurrence took place in the airspace between Hawaii and northeast Asia, in the Hawaii/Japan traffic flow (JPHAWA). The primary cause of this occurrence was ATC loop error, loss of situational awareness (category D). There was an Altitude Reservation (ALTRV) operation in the vicinity; however, the aircraft operation involved in this occurrence was not part of the ALTRV. ATC assumed the flight was part of the ALTRV; otherwise, this flight would have been re-routed around the ALTRV. The scrutiny group estimated that the aircraft spent 59 minutes of travel time before the aircraft profile was correctly entered into the automation system. The other reported LLD occurred in November 2021 within the South Pacific (SOPAC) traffic flow. In this occurrence, the procedures established to inform the ATC automation system with restricted airspace information were not completed. The scrutiny group estimated the aircraft involved spent 5 minutes of unprotected time before the information in the automation system was corrected.

**Table 6.** Trends in reported LLDs by category, 2018 - 2021

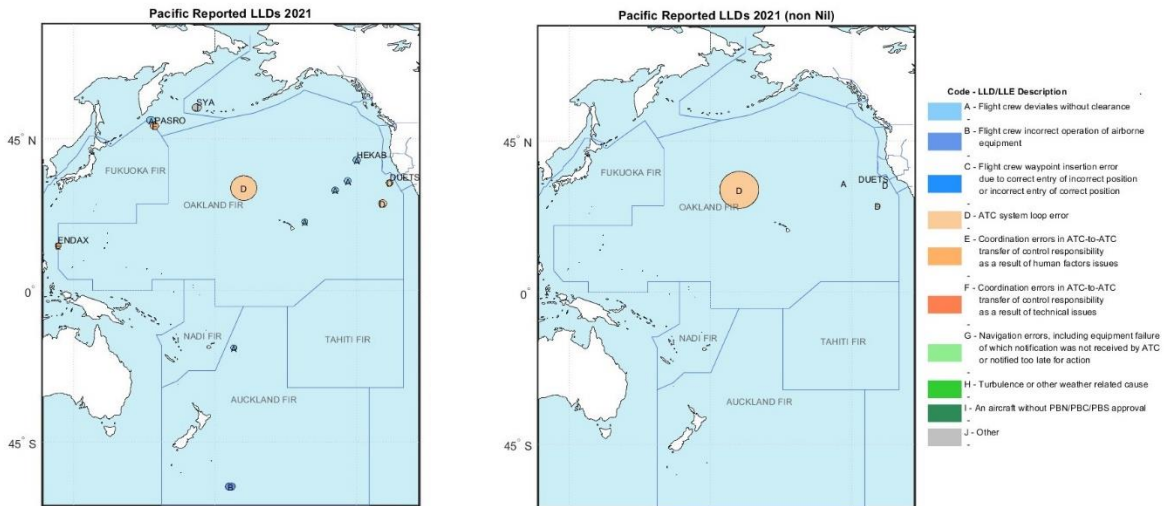
LLD Category	2018	2019	2020	2021
<b>A</b>	14	9	6	6
<b>B</b>	7	3	1	1
<b>C</b>	0	0	0	0
<b>D</b>	2	1	0	3
<b>E</b>	9	11	1	2
<b>F</b>	0	0	0	0
<b>G</b>	1	2	0	0
<b>H</b>	0	0	1	0
<b>I</b>	0	0	0	0
<b>J</b>	1	0	1	1
<b>Totals</b>	34	26	10	13



**Figure 3:** Trend in reported LLDs for categories related to aircrew (counts of LLD reports)



**Figure 4:** Trend in reported LLDs for categories related to ATC (counts of LLD reports)



**Figure 5a:** All Reported LLDs – 2021

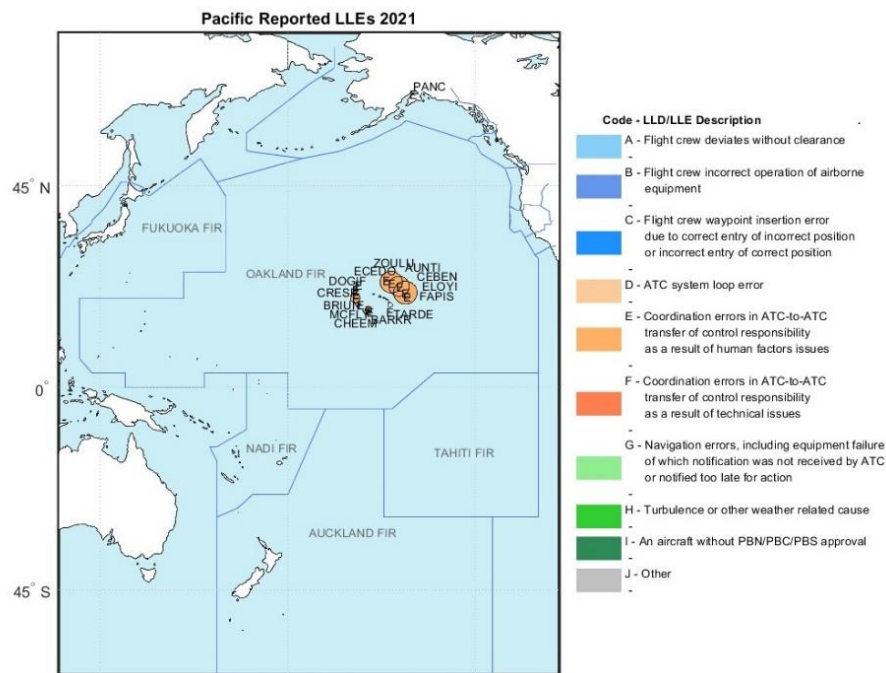
**Figure 5b:** Non Nil Reported LLDs – 2021

3.12 Trends Observed in Reported Large Longitudinal Errors (LLEs)

3.13 **Table 7** shows the trends in the number of reported LLEs by category for calendar years 2018 through 2021. Table 4 provides a description of the categories. The high number of category E reported LLEs are due to reports for transfer errors between Honolulu Control Facility (HCF) and Oakland Oceanic FIR. There were ninety-eight of these reported category E LLEs between HCF and Oakland Oceanic FIR in 2021. **Figure 6** shows the locations for the reported LLEs in 2021.

**Table 7.** Trends in reported LLEs by category, 2018 through 2021

Category	2018	2019	2020	2021
A	0	1	0	0
B	1	0	0	0
C	0	0	0	0
D	0	0	0	0
E	2	62	64	98
F	1	1	0	0
G	0	0	0	0
H	0	0	0	0
I	1	0	0	0
<b>Total</b>	<b>5</b>	<b>64</b>	<b>64</b>	<b>98</b>



**Figure 6:** Reported LLE locations in Pacific airspace - 2021

3.14 The scrutiny review group informed PARMO these LLE occurrences between HCF and Oakland center affect the User Preferred Routes (UPRs) crossing fixed airways within Oakland Oceanic FIR. These type of events occur frequently and require significant resources at the ATC facility to investigate underlying causes.

3.15 A task force was established to further investigate these occurrences and determine remedial actions, the task force met at the HCF early in 2021. The task force reviewed the current systems and procedures at the HCF. It was determined that the HCF does not have the functionality to update the

aircraft profile and transfer the updated information to the next facility. The current automation system includes the Surveillance Data Processing (SDP) Microprocessor En Route Automated Radar Tracking System (Micro-EARTS) and the Offshore Flight Data Processing System (OFDPS). The FAA's offshore modernization plan had been delayed for many years due to higher priorities. The current plan to implement the En Route Automation Modernization (ERAM) system at the HCF is still on track for implementation by the end of 2025. Prior to that time, both facilities have implemented mitigation strategies:

3.15.1 A procedure that requires the controller to determine the remaining travel time to the boundary fix is in use by the HCF. During this procedure, ATC computes an estimated time of arrival (ETA) for the boundary fix and manually transfers the ETA to the next facility. It is noted that this is a manual procedure and is considered to be a short-term solution.

3.15.2 Oakland center has implemented refresher training for the oceanic controllers. This training instructs the controllers on how to update an aircraft's profile/fix times using the coordination window within the ATC automation system.

3.15.3 All of the reported occurrences of this type were validated by Oakland center using the radar information or ADS-C position information from the aircraft. There were extended periods in which the radar used for this validation was out of service, specifically from November 2021 through March 2022. During the outage periods, there are fewer reported occurrences due to the limited investigation and validation of such occurrences.

#### **4. Horizontal Risk Assessment and Safety Oversight for Pacific Airspace**

##### **4.1 Collision Risk Model (CRM) Parameters**

4.2 To calculate a lateral risk estimate for Pacific airspace, each reported large lateral deviation is examined to determine the time spent on an incorrect route and the number of tracks crossed without ATC clearance. This process is similar to that done for reported large height deviations (LHDs) except that the capabilities of the aircraft are considered due to the requirements for the different lateral separation minima. This methodology is used for lateral risk estimates in North Atlantic (NAT) airspace. This methodology provides a lateral risk estimate for the entire airspace rather than lateral risk estimates for specific portions of operations.

4.3 To determine whether time spent on an incorrect route and/or tracks crossed without clearance are appropriate, each reported occurrence is examined. The capabilities of the aircraft determine the appropriate Lateral Infringement Distance (LID). If the occurrence involves a lateral deviation from a cleared route, the magnitude of the deviation is compared to the appropriate LID. Based on the available lateral separation minima in Pacific airspace, the current LIDs are:

4.3.1 15 NM if the aircraft is eligible for a 23-NM lateral separation standard, therefore, is RNP4, RCP240 and RSP180 equipped (23 NM – 4 NM [RNP4] – 4 NM [2 × SLOP to account for opposite direction traffic])

4.3.2 36 NM if the aircraft is RNP10 (50 NM – 10 NM [RNP10] – 4 NM [2 × SLOP to account for opposite direction traffic])

4.4 The same risk-weighting method by traffic flows used in the calculation of the vertical risk is applied in the calculation of lateral risk. The values of the parameters in the CRM used to estimate risk in Pacific RVSM airspace, are summarized in **Table 8**. Other collision risk model parameters that vary by traffic flow include aircraft size and flying hours. These parameters are shown in **Table 9** by traffic flow.

**Table 8:** Estimates of the parameters in the horizontal CRM for Pacific airspace

Parameter	Description	Value
$ \overline{\Delta V} $	Average relative same-direction speed	13 Knots
$ \overline{V} $	Average aircraft speed	480 knots
$ \overline{\dot{z}} $	Average relative vertical speed during loss of vertical separation	1.5 knots
$ \overline{j'_o} $	Average absolute relative cross track speed for aircraft nominally on the same track.	5 knots
$ \overline{y'_{60}} $	Average absolute relative cross track speed when one aircraft has committed a 1° waypoint insertion error.	80 knots
$Ey(\text{same})$	Same direction lateral occupancy, estimated from TSD	0.0206
$Ey(\text{opp})$	Opposite direction lateral occupancy, estimated from TSD	0.0000
$P_z(0)$	Probability two aircraft at the same nominal level are in vertical overlap	0.42
T	ADS-C periodic report frequency	10 minutes

**Table 9:** Horizontal CRM Parameters that Vary by Traffic Flow

Traffic Flow	Annual Flying Hours	Percent	Average Aircraft Length, $\lambda_x$ (NM)	Average Aircraft Wingspan, $\lambda_y$ (NM)	Average Aircraft Height, $\lambda_z$ (NM)
NOPAC	238,771.3	20.29%	0.037	0.034	0.010
CENPAC	310,386.1	26.38%	0.037	0.035	0.010
CEP	461,989.7	39.26%	0.026	0.023	0.007
JPHAWA	20,000.0	1.70%	0.033	0.031	0.009
JPGUAM	6,000.0	0.51%	0.025	0.023	0.008
OTHER	12,786.4	1.09%	0.030	0.027	0.008
AUSNZSP	39,000.0	3.31%	0.025	0.023	0.007
NADI	15,000.0	1.27%	0.031	0.030	0.009
AUSNZJP	15,584.8	1.32%	0.034	0.033	0.009
SOPAC	57,218.9	4.86%	0.034	0.033	0.009
<b>TOTAL</b>	<b>1,176,737.3</b>	<b>100.00%</b>	<b>0.032 NM</b>	<b>0.029 NM</b>	<b>0.009 NM</b>
			<b>192.5 ft</b>	<b>178.0 ft</b>	<b>52.7 ft</b>

4.5 **Risk Estimation Results.** The results for the lateral and longitudinal risk for Pacific airspace are detailed in **Table 10**. The risk estimates meet the specified TLS value of  $5.0 \times 10^{-9}$  fapfh.

4.6 The estimate of overall lateral risk for 2021 increased from the estimate provided for calendar year 2020.

**Table 10:** Pacific Airspace Horizontal Risk Estimates

<b>Pacific Airspace – estimated annual flying hours = 1,176,737.3 hours</b> <i>(note: estimated hours based on Dec 2021 traffic sample data)</i>			
<b>Source of Risk</b>	<b>Risk Estimation</b>	<b>TLS</b>	<b>Remarks</b>
<i>RASMAG 25 Lateral Risk</i>	$0.09 \times 10^{-9}$	$5.0 \times 10^{-9}$	<i>Below TLS</i>
<i>RASMAG 25 30NM Longitudinal Risk</i>	$4.08 \times 10^{-9}$	$5.0 \times 10^{-9}$	<i>Below TLS</i>
<i>RASMAG 25 50NM Longitudinal Risk</i>	$2.22 \times 10^{-9}$	$5.0 \times 10^{-9}$	<i>Below TLS</i>
Lateral Risk	<b><math>1.74 \times 10^{-9}</math></b>	$5.0 \times 10^{-9}$	<b>Below TLS</b>
30NM Longitudinal Risk	<b><math>4.08 \times 10^{-9}</math></b>	$5.0 \times 10^{-9}$	<b>Below TLS</b>
50NM Longitudinal Risk	<b><math>2.22 \times 10^{-9}</math></b>	$5.0 \times 10^{-9}$	<b>Below TLS</b>

4.7 **Figure 7** presents the lateral and longitudinal collision risk estimate trends during the period from January to December 2021.

4.8 The estimates of longitudinal collision risk remain constant from the previous year. This result is due to the use of the Anderson-Hsu collision risk model; which was developed to support the distance-based longitudinal separation minima. The input parameters to this model include assumptions about the performance of the communication, navigation, and surveillance systems. ICAO Document 9869, *Performance-based Communication and Surveillance (PBCS) Manual*, and ICAO Document 10037, the *Global Operational Data Link (GOLD) Manual*, provide guidance for the use of the communication and surveillance systems needed for the distance-based longitudinal separation minima. The assumptions related to the aircraft navigation systems include lateral path-keeping performance (e.g. RNP 4).

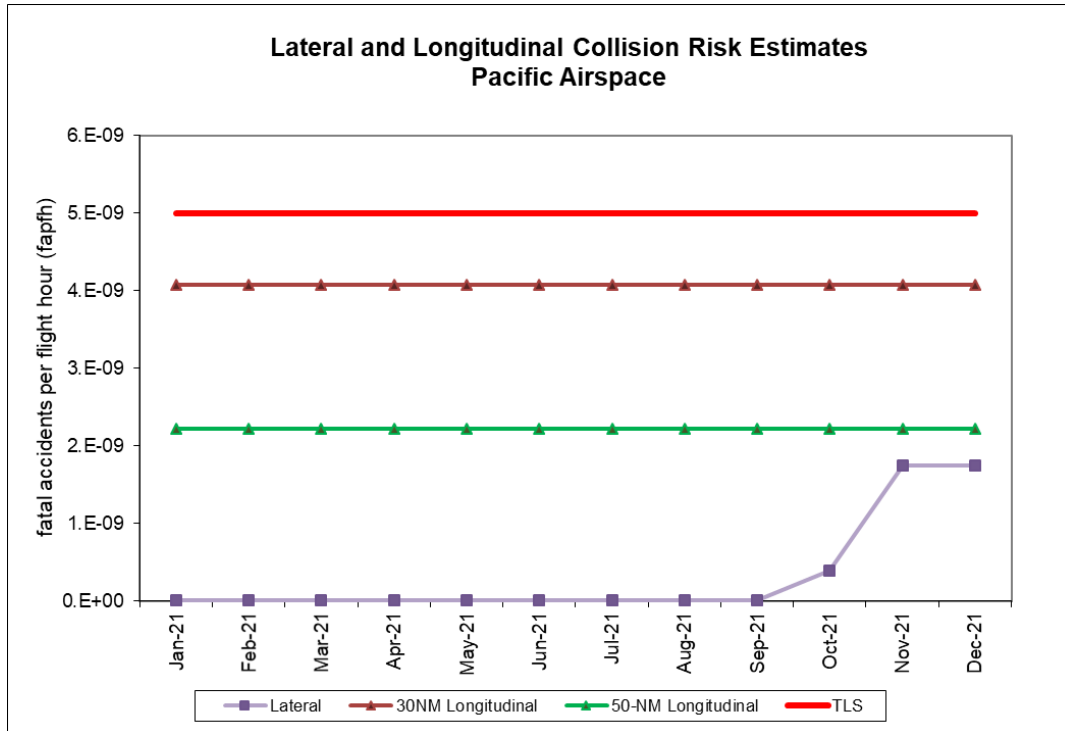
4.9 The underlying CRM assumptions require ongoing monitoring to ensure the aircraft and airspace using these standards continue to meet the modeled assumptions. The ICAO Separation and Airspace Safety Panel (SASP) is documenting the monitoring requirements for reduced longitudinal separation standards in the upcoming second edition of the ICAO Doc 10063, *Manual on Monitoring the Application of Performance-based Horizontal Separation Minima*. The next section provides the results of the longitudinal monitoring process for the NOPAC traffic flow within the Anchorage Oceanic FIR. The details of the analysis is contained in Attachment B.

## 5. Longitudinal Monitoring Results

5.1 The analysis in Attachment B utilized a December 2021 traffic sample for the Anchorage Oceanic FIR and observed 2,247 longitudinal aircraft pairs operating on the same-identical route and 165 aircraft pairs operating on crossing routes. As expected, due to the airspace structure and the NOPAC traffic flow, most of the observed longitudinal pairs were operating on the same route. There were fewer longitudinal aircraft pairs operating on crossing/intersecting routes.

5.2 The data in Attachment B provides the estimated longitudinal collision risk assuming the longitudinal separation between aircraft pairs is uniformly distributed for aircraft on same-identical tracks

as  $0.61 \times 10^{-9}$  fapfh. The actual longitudinal spacing for aircraft pairs observed on same-identical tracks gives a lower estimated collision risk of  $0.004 \times 10^{-9}$  fapfh.



**Figure 7:** Trends of Horizontal Risk Estimates for Pacific Airspace

## Longitudinal Monitoring Analysis for the Anchorage Oceanic FIR December 2021

Prepared by  
Pacific Approvals and Registry Monitoring Organization (PARMO) – August 2022  
(An ICAO APANPIRG approved Enroute Monitoring Agency)

### 1. Introduction

1.1 This report provides the longitudinal monitoring process details applied to the Anchorage Oceanic Airspace. The methodology was developed by the ICAO Separation and Airspace Safety Panel (SASP) for performance-based reduced longitudinal separation standards. The ICAO SASP is documenting this process in the upcoming second edition of the ICAO Doc 10063, *Manual on Monitoring the Application of Performance-based Horizontal Separation Minima*.

### 2. Discussion

2.1 The longitudinal monitoring method examines the separation between aircraft pairs in terms of distance and time. The observed spacing between aircraft pairs is compared to the distribution of aircraft spacing assumed in the collision risk model. In addition, a longitudinal risk estimate is derived from the observations.

2.2 The analysis in this paper utilizes an extensive data set from the Anchorage Oceanic FIR. The traffic data include all available aircraft positions within the Anchorage Oceanic FIR received via ADS-C and HF voice from December 2021. The CPDLC messages with flight level change clearances and LEVEL reports from pilots are used for interpolation throughout the methodology.

2.3 The process identified the compulsory position reports for each flight. Next, the reported positions 20 minutes prior to and 20 minutes after the waypoint position report were compared with position reports from other flights on the same day. If two or more consecutive common points were identified, the aircraft pair was considered to be operating on the same-identical route for at least a portion of the travel through Anchorage Oceanic FIR. If only one common point was identified, the aircraft pair was considered to be operating on crossing routes. Aircraft pairs operating on intersecting routes where the intersection point does not occur over a common point are also identified.

2.4 These data were further filtered by the reported FL for both aircraft. If the reported FLs were within 500-ft of each other, the aircraft pair was considered to possibly be occupying the same FL.

#### 2.5 *Same Identical Routes*

2.5.1. The criteria used to identify a longitudinal aircraft pair operating on same identical route is as follows:

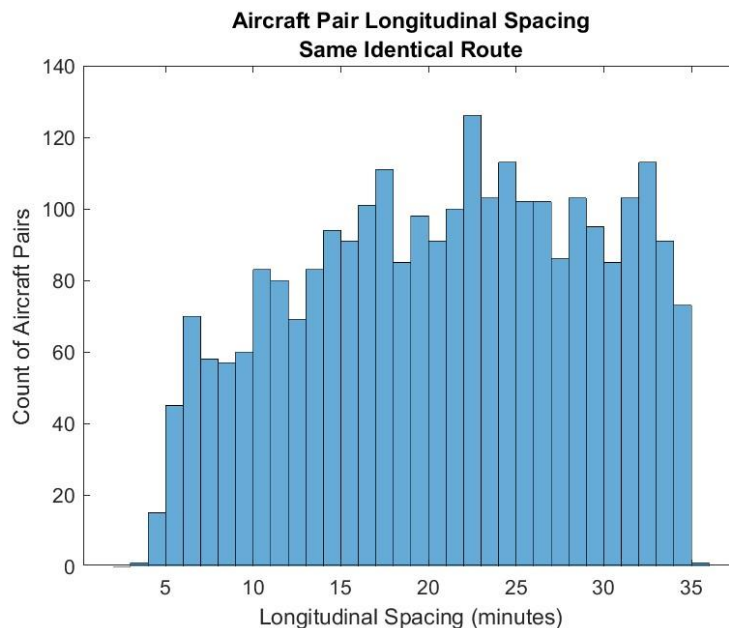
- The compulsory waypoints for the aircraft pair are the same
- There are at least two compulsory waypoints in common for the aircraft pair
- The difference in the reported altitude from both aircraft over the same waypoints is within 500 ft
- The time difference between the two aircraft over the waypoints is a maximum of 35 minutes. Longitudinal spacing of 35 minutes corresponds to the separation distance considered in the CRM for the 30NM longitudinal separation minimum (35 minutes × 8NM/minute = 280NM).
- The distance measured between the pair at the time the lead aircraft is over the first common waypoint is a maximum of 280NM.

2.5.2. During December 2021, there were 2,427 observed aircraft pairs meeting the above criteria over common waypoints. This value does not represent unique observations, each of the identified aircraft pairs were in longitudinal separation over at least two common waypoints.

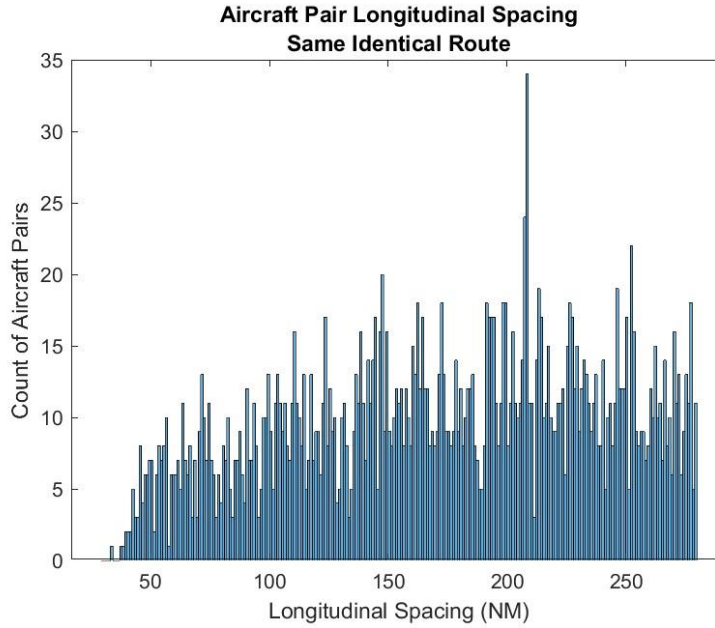
2.5.3. **Figure 1** shows the histogram of the longitudinal separation for aircraft pairs on same-identical routes in terms of time. There was one aircraft pair observed with less than the minimum longitudinal separation, the aircraft involved in this pair were State aircraft operations that were part of an ALTRV. These State aircraft operations are removed from the analysis in this paper.

2.5.4. **Figure 2** shows the same data, in terms of distance instead of time, for aircraft pairs on same-identical routes. The smallest allowable longitudinal separation in the Anchorage Oceanic FIR is 30NM. The traffic data available for this analysis does not provide the planned separation for the aircraft pairs, only the observed longitudinal spacing is observed.

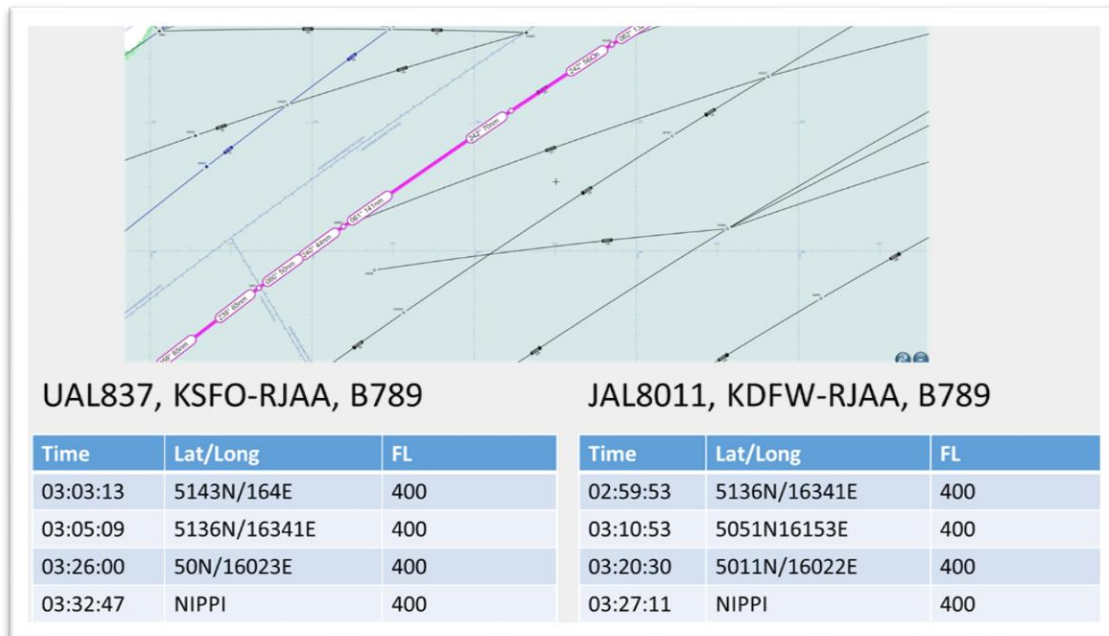
2.5.5. An example of an observed longitudinal aircraft pair is provided in **Figure 3**. The two aircraft operations were observed on 16 December 2021, on airway R220 in the Anchorage Oceanic FIR. The aircraft identifications are UAL837 [KSFO-RJAA] and JAL8011 [KDFW-RJAA], both westbound aircraft operations following the same routing within the NOPAC traffic flow. Both aircraft were operating on F400, with JAL8011 five minutes thirty-six seconds ahead of UAL837 over NIPPI. These two aircraft were both B788, filed RCP240, RSP180 and RNP4



**Figure 1.** Longitudinal Separation Histogram for Aircraft Pairs on Same-Identical Tracks – time



**Figure 2.** Longitudinal Separation Histogram for Aircraft Pairs on Same-Identical Tracks – distance



**Figure 3.** Longitudinal Separation Example – crossing tracks

## 2.6 Crossing and Intersecting Routes

2.6.1. The longitudinal process identifies aircraft pairs operating on crossing routes where the intersection occurs over either a common waypoint or between waypoints. The criteria used to identify a longitudinal aircraft pair operating on crossing or intersecting routes is as follows:

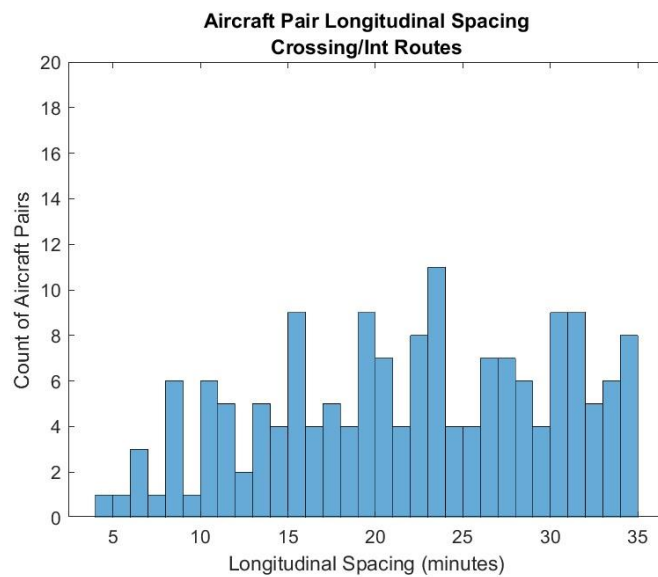
- For crossing routes, there is only one common compulsory waypoints for the aircraft pair

- For intersecting routes, there are no common compulsory waypoints for the aircraft pair. Their routes intersect between compulsory waypoints.
- The difference in the reported altitude from both aircraft at the intersection is within 500 ft.
- The time difference between the two aircraft at the intersection is a maximum of 35 minutes. Longitudinal spacing of 35 minutes corresponds to the separation distance considered in the CRM for the 30NM longitudinal separation minimum ( $35 \text{ minutes} \times 8\text{NM/minute} = 280\text{NM}$ ).
- The distance measured between the pair at the time the lead aircraft is over the intersection is a maximum of 280NM.
- The process measures the relative angle between the two aircraft at the crossing/intersection point. The risk model used to determine the 30NM longitudinal separation minimum allowed for crossing/intersecting angles up to 45 degrees.

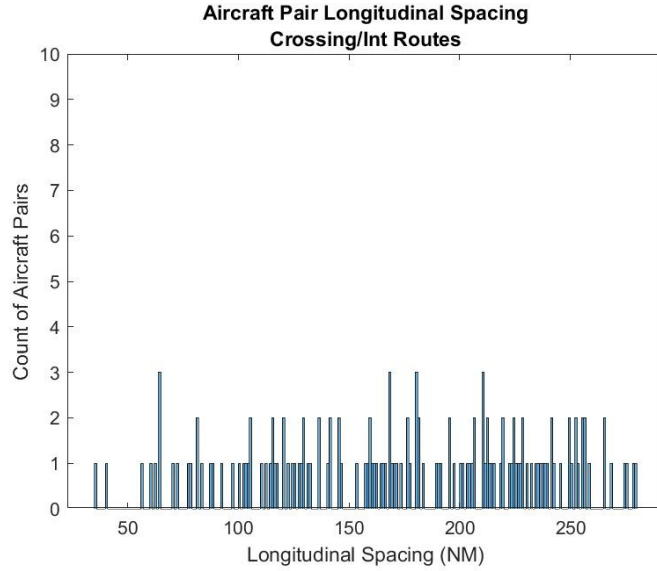
2.6.2. The number of aircraft pairs observed on crossing routes where the intersection occurs over a common waypoint was 165 within the December 2021 traffic sample. There were no aircraft pairs observed on crossing routes where the intersection occurs between waypoints in the traffic data sample.

2.6.3. **Figures 4 and 5** contain the histograms of observed longitudinal spacing for aircraft pairs observed on crossing routes. Figure 4 provides the histogram in terms of time (minutes) and Figure 5 provides the same data in terms of distance (NM).

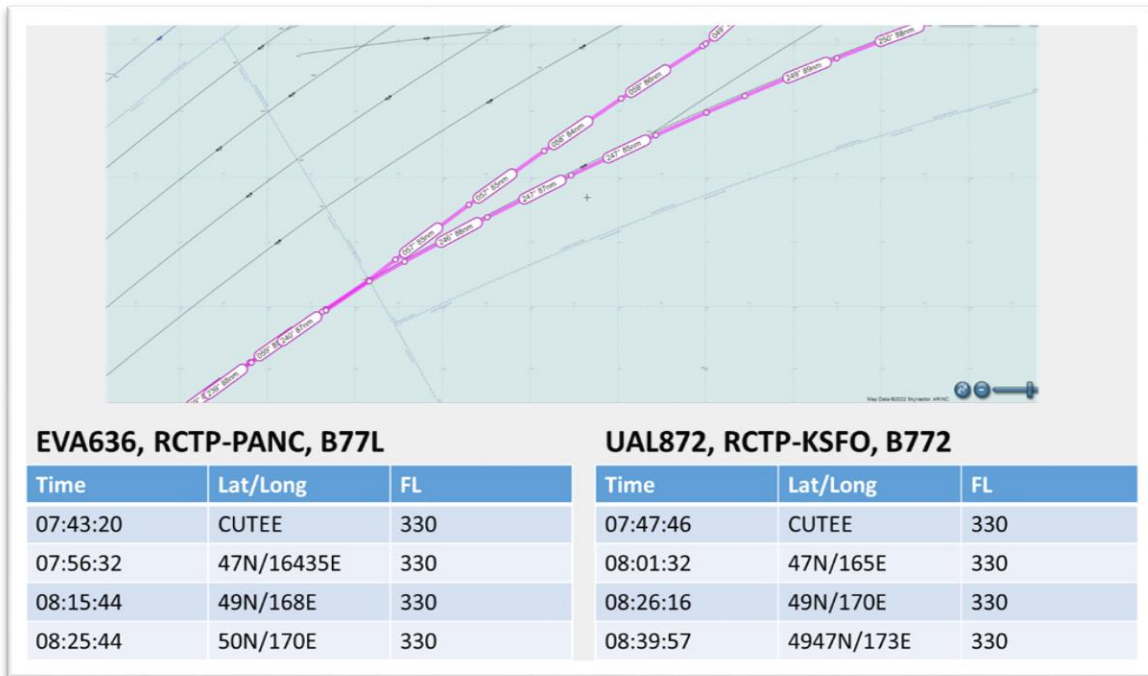
2.6.4. An example of an observed longitudinal aircraft pair on crossing routes is provided in **Figure 6**. The two aircraft operations were observed on 19 December 2021 within Anchorage Oceanic FIR. The aircraft identifications are EVA636 [B77L, RCTP-PANC] and UAL872 [B772, RCTP-KSFO], both eastbound aircraft operations. The aircraft pair entered Anchorage Oceanic FIR over the boundary fix CUTEE on F330. The crossing point for this aircraft pair is over CUTEE, after CUTEE the routings diverge. The separation in terms of time is 4.4 minutes, the longitudinal distance separation measured when the lead aircraft, EVA636, is over the crossing point is 40.5 NM. The relative heading for this aircraft pair is 0.01 degrees. These two aircraft filed RCP240, RSP180 and RNP4



**Figure 4.** Longitudinal Separation Histogram for Aircraft Pairs on Crossing/Intersecting Routes – time



**Figure 5.** Longitudinal Separation Histogram for Aircraft Pairs on Crossing/Intersecting Routes – distance



**Figure 6.** Longitudinal Separation Example – crossing tracks

2.7. Longitudinal Monitoring Methodology

2.7.1. The Anderson-Hsu collision risk model has provided the basis for the SASP in the development of the distance-based procedural longitudinal separation standards. This model was first described in *ICAO Doc 9689, Appendix 1* (reference 1). The Anderson-Hsu model was used to develop the 30NM and 50NM longitudinal separation minima currently in use in Pacific airspace. The Anderson-Hsu model makes use of a controller-intervention buffer, which accounts for the time it takes ATC to communicate instructions

to a pilot, the time for the pilot to react and initiate an appropriate manoeuvre, and the time for the aircraft to achieve a change in trajectory sufficient to prevent a collision. These assumptions were used in the development of the Required Communication Performance (RCP) 240 and Required Surveillance Performance (RSP) 180 specifications.

2.7.2. The collision risk at each distance,  $S_i$ , is calculated using the Anderson-Hsu model from the assumptions for the controller-intervention buffer under normal and non-normal surveillance and communication conditions. Equation 1 shows the risk estimate computed as a weighted average of the risk values for the separate scenarios of the controller-intervention buffer:

$$CR = 0.95 \times (0.95 \times CR(4 \text{ minutes}) + 0.05 \times CR(10.5 \text{ minutes})) + 0.05 \times CR(13.5 \text{ minutes}) \quad [1]$$

2.7.3. Using this model, the initial separation between aircraft pairs is assumed to be uniformly distributed between the separation minimum and  $250\text{NM} + S_i$ , e.g.  $U[30,280]$ . Prior to the availability of the 30NM and 50NM separation standards, the longitudinal separation minimum was 10 minutes, or approximately 80NM. The second edition of Doc 10063 will contain a similar methodology for estimating collision risk from observed aircraft spacing.

2.7.4. **Appendix A** provides the methodology to estimate longitudinal risk for aircraft pairs operating on same routes. The third column in the Appendix A table is the count of aircraft pairs observed at the separation distance listed in the second column of the table, the bin width is 1NM. The fourth column contains the collision risk (CR) value for the separation distance listed in the second column. This value is provided by a programmed version of the Anderson-Hsu model using equation [1] and the following parameters for the Anchorage Oceanic FIR.

- Periodic report rate for ADS-C aircraft is 576 seconds (9.6 minutes) = T
- RNP 4 is the navigation performance requirement
- Average aircraft speed is 480 knots
- Maximum modelled change in aircraft speed is 100 knots
- Speed error parameter,  $\lambda v = 6.84$  knots
- Number of Pairs,  $NP, 1/T = 6.25$
- $\lambda_{xy} = 192.4$  ft
- $\lambda_z = 52.7$  ft
- $P_z(0) = 0.48$
- $|\bar{z}| = 1.5$  knots

2.7.5. All of the observed aircraft pair separations for aircraft operating on same-identical tracks were included in the counts provided in Appendix A. The data sets used in this analysis included all observed longitudinal pairs. Some of the aircraft pairs with larger observed separation distances may not be eligible for the 30 NM longitudinal separation.

2.7.6. The data in Appendix A provides the estimated longitudinal collision risk assuming the longitudinal separation between aircraft pairs is uniformly distributed for aircraft on same-identical tracks as  $0.61 \times 10^{-9}$  fapfh. The actual longitudinal spacing for aircraft pairs on same-identical tracks gives a lower estimated collision risk of  $0.004 \times 10^{-9}$  fapfh.

### References

1. ICAO, *Manual on Airspace Planning Methodology for the Determination of Separation Minima*, ICAO Doc 9689, First Edition, 1998.

## **Appendix A Longitudinal Monitoring Collision Risk**

**Same Identical Tracks – Anchorage Oceanic FIR**

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, $U[30, 280]$	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
1	29	0	5.58E-08	0.004	0.000	2.23E-10	0.00E+00
2	30	0	3.54E-08	0.004	0.000	1.42E-10	0.00E+00
3	31	0	2.24E-08	0.004	0.000	8.98E-11	0.00E+00
4	32	0	1.43E-08	0.004	0.000	5.70E-11	0.00E+00
5	33	0	9.05E-09	0.004	0.000	3.62E-11	0.00E+00
6	34	1	5.75E-09	0.004	0.000	2.30E-11	2.37E-12
7	35	0	3.64E-09	0.004	0.000	1.46E-11	0.00E+00
8	36	0	2.31E-09	0.004	0.000	9.22E-12	0.00E+00
9	37	0	1.45E-09	0.004	0.000	5.82E-12	0.00E+00
10	38	1	9.14E-10	0.004	0.000	3.65E-12	3.76E-13
11	39	1	5.71E-10	0.004	0.000	2.29E-12	2.35E-13
12	40	2	3.56E-10	0.004	0.001	1.42E-12	2.93E-13
13	41	2	2.21E-10	0.004	0.001	8.83E-13	1.82E-13
14	42	2	1.36E-10	0.004	0.001	5.46E-13	1.12E-13
15	43	5	8.40E-11	0.004	0.002	3.36E-13	1.73E-13
16	44	3	5.16E-11	0.004	0.001	2.06E-13	6.38E-14
17	45	3	3.16E-11	0.004	0.001	1.26E-13	3.91E-14
18	46	8	1.93E-11	0.004	0.003	7.73E-14	6.37E-14
19	47	4	1.18E-11	0.004	0.002	4.71E-14	1.94E-14
20	48	6	7.17E-12	0.004	0.002	2.87E-14	1.77E-14
21	49	6	4.36E-12	0.004	0.002	1.74E-14	1.08E-14
22	50	7	2.64E-12	0.004	0.003	1.06E-14	7.63E-15
23	51	7	1.60E-12	0.004	0.003	6.41E-15	4.62E-15
24	52	2	9.69E-13	0.004	0.001	3.87E-15	7.98E-16
25	53	6	5.85E-13	0.004	0.002	2.34E-15	1.45E-15
26	54	8	3.53E-13	0.004	0.003	1.41E-15	1.16E-15
27	55	7	2.12E-13	0.004	0.003	8.49E-16	6.12E-16
28	56	8	1.28E-13	0.004	0.003	5.11E-16	4.21E-16
29	57	10	7.66E-14	0.004	0.004	3.06E-16	3.16E-16
30	58	1	4.59E-14	0.004	0.000	1.84E-16	1.89E-17
31	59	6	2.74E-14	0.004	0.002	1.10E-16	6.78E-17
32	60	6	1.64E-14	0.004	0.002	6.55E-17	4.05E-17
33	61	6	9.74E-15	0.004	0.002	3.90E-17	2.41E-17
34	62	7	5.78E-15	0.004	0.003	2.31E-17	1.67E-17
35	63	5	3.43E-15	0.004	0.002	1.37E-17	7.06E-18
36	64	11	2.02E-15	0.004	0.005	8.09E-18	9.17E-18
37	65	7	1.19E-15	0.004	0.003	4.76E-18	3.43E-18
38	66	6	6.97E-16	0.004	0.002	2.79E-18	1.72E-18

RASMAG/27-WP/21  
Attachment B

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, $U[30, 280]$	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
39	67	8	4.07E-16	0.004	0.003	1.63E-18	1.34E-18
40	68	3	2.36E-16	0.004	0.001	9.45E-19	2.92E-19
41	69	7	1.36E-16	0.004	0.003	5.45E-19	3.93E-19
42	70	3	7.81E-17	0.004	0.001	3.13E-19	9.66E-20
43	71	9	4.44E-17	0.004	0.004	1.78E-19	1.65E-19
44	72	13	2.49E-17	0.004	0.005	9.98E-20	1.34E-19
45	73	10	1.38E-17	0.004	0.004	5.52E-20	5.68E-20
46	74	7	7.48E-18	0.004	0.003	2.99E-20	2.16E-20
47	75	11	3.99E-18	0.004	0.005	1.60E-20	1.81E-20
48	76	7	2.10E-18	0.004	0.003	8.42E-21	6.07E-21
49	77	6	1.10E-18	0.004	0.002	4.39E-21	2.71E-21
50	78	3	5.67E-19	0.004	0.001	2.27E-21	7.00E-22
51	79	6	2.91E-19	0.004	0.002	1.16E-21	7.19E-22
52	80	4	1.48E-19	0.004	0.002	5.93E-22	2.44E-22
53	81	8	7.52E-20	0.004	0.003	3.01E-22	2.48E-22
54	82	7	3.80E-20	0.004	0.003	1.52E-22	1.09E-22
55	83	10	1.91E-20	0.004	0.004	7.63E-23	7.86E-23
56	84	5	9.56E-21	0.004	0.002	3.82E-23	1.97E-23
57	85	3	4.78E-21	0.004	0.001	1.91E-23	5.90E-24
58	86	7	2.38E-21	0.004	0.003	9.51E-24	6.86E-24
59	87	7	1.18E-21	0.004	0.003	4.73E-24	3.41E-24
60	88	9	5.86E-22	0.004	0.004	2.34E-24	2.17E-24
61	89	6	2.90E-22	0.004	0.002	1.16E-24	7.16E-25
62	90	4	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
63	91	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
64	92	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
65	93	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
66	94	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
67	95	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
68	96	3	0.00E+00	0.004	0.001	0.00E+00	0.00E+00
69	97	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
70	98	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
71	99	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
72	100	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
73	101	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
74	102	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
75	103	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
76	104	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
77	105	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
78	106	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, $U[30, 280]$	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
79	107	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
80	108	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
81	109	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
82	110	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
83	111	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
84	112	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
85	113	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
86	114	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
87	115	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
88	116	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
89	117	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
90	118	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
91	119	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
92	120	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
93	121	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
94	122	6	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
95	123	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
96	124	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
97	125	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
98	126	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
99	127	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
100	128	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
101	129	4	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
102	130	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
103	131	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
104	132	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
105	133	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
106	134	3	0.00E+00	0.004	0.001	0.00E+00	0.00E+00
107	135	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
108	136	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
109	137	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
110	138	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
111	139	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
112	140	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
113	141	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
114	142	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
115	143	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
116	144	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
117	145	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
118	146	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00

RASMAG/27-WP/21  
Attachment B

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, U[30, 280]	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
119	147	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
120	148	20	0.00E+00	0.004	0.008	0.00E+00	0.00E+00
121	149	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
122	150	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
123	151	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
124	152	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
125	153	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
126	154	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
127	155	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
128	156	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
129	157	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
130	158	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
131	159	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
132	160	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
133	161	15	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
134	162	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
135	163	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
136	164	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
137	165	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
138	166	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
139	167	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
140	168	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
141	169	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
142	170	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
143	171	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
144	172	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
145	173	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
146	174	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
147	175	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
148	176	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
149	177	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
150	178	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
151	179	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
152	180	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
153	181	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
154	182	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
155	183	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
156	184	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
157	185	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
158	186	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, $U[30, 280]$	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
159	187	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
160	188	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
161	189	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
162	190	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
163	191	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
164	192	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
165	193	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
166	194	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
167	195	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
168	196	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
169	197	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
170	198	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
171	199	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
172	200	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
173	201	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
174	202	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
175	203	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
176	204	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
177	205	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
178	206	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
179	207	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
180	208	24	0.00E+00	0.004	0.010	0.00E+00	0.00E+00
181	209	34	0.00E+00	0.004	0.014	0.00E+00	0.00E+00
182	210	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
183	211	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
184	212	3	0.00E+00	0.004	0.001	0.00E+00	0.00E+00
185	213	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
186	214	19	0.00E+00	0.004	0.008	0.00E+00	0.00E+00
187	215	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
188	216	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
189	217	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
190	218	15	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
191	219	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
192	220	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
193	221	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
194	222	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
195	223	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
196	224	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
197	225	6	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
198	226	15	0.00E+00	0.004	0.006	0.00E+00	0.00E+00

RASMAG/27-WP/21  
Attachment B

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, $U[30, 280]$	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
199	227	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
200	228	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
201	229	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
202	230	15	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
203	231	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
204	232	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
205	233	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
206	234	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
207	235	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
208	236	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
209	237	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
210	238	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
211	239	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
212	240	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
213	241	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
214	242	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
215	243	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
216	244	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
217	245	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
218	246	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
219	247	19	0.00E+00	0.004	0.008	0.00E+00	0.00E+00
220	248	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
221	249	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
222	250	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
223	251	17	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
224	252	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
225	253	22	0.00E+00	0.004	0.009	0.00E+00	0.00E+00
226	254	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
227	255	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
228	256	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
229	257	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
230	258	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
231	259	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
232	260	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
233	261	12	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
234	262	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
235	263	15	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
236	264	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
237	265	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
238	266	7	0.00E+00	0.004	0.003	0.00E+00	0.00E+00

Index	Dist, $S_i$	Observed Count, $[S_{i-1} < x_i \leq S_i]$	$CR(S_i)$ , Risk Value	Modelled Separation Distribution, U[30, 280]	Observed Separation Distribution	$CRE(S_i)$ for Modeled Uniform Dist	$CRE(S_i)$ for Observed AC Seps
239	267	14	0.00E+00	0.004	0.006	0.00E+00	0.00E+00
240	268	8	0.00E+00	0.004	0.003	0.00E+00	0.00E+00
241	269	10	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
242	270	6	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
243	271	16	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
244	272	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
245	273	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
246	274	6	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
247	275	9	0.00E+00	0.004	0.004	0.00E+00	0.00E+00
248	276	13	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
249	277	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
250	278	18	0.00E+00	0.004	0.007	0.00E+00	0.00E+00
251	279	5	0.00E+00	0.004	0.002	0.00E+00	0.00E+00
252	280	11	0.00E+00	0.004	0.005	0.00E+00	0.00E+00
<b>Totals</b>		<b>2,427</b>				<b><math>0.61 \times 10^{-9}</math></b>	<b><math>0.004 \times 10^{-9}</math></b>