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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 VERTICAL SAFETY MONITORING REPORT 2021

(Presented by United States/PARMO)

##### SUMMARY

This paper compares actual performance to safety goals that support the continued use of reduced vertical separation minimum (RVSM) in Pacific and a portion of North East Asia airspace. This report contains a summary of large height deviation (LHD) reports received by the Pacific Approvals Registry and Monitoring Organization (PARMO) for the most recent reporting period of 1 January to 31 December 2021. There are a total of 68 reported large height deviations (LHDs) accounting for 308.52 minutes of operation at incorrect flight level in Pacific and a portion of North East Asia RVSM airspace. This report also contains an estimate of the vertical collision risk. The 2021 vertical collision risk estimate for Pacific airspace exceeds the target level of safety (TLS) value of  $5.0 \times 10^{-9}$  fatal accidents per flight hour. The 2021 vertical collision risk estimate for a portion of North East Asia airspace meets the TLS value of  $5.0 \times 10^{-9}$  fatal accidents per flight hour.

## 1. INTRODUCTION

1.1 The Pacific Approvals Registry and Monitoring Organization (PARMO) produces an annual report for Pacific and North East Asia airspace. 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 safety monitoring report for the time period 1 January to 31 December 2021. This paper contains a summary of large height deviation reports, and estimates of vertical risk for Pacific and North East Asia airspace.

## 2. DISCUSSION

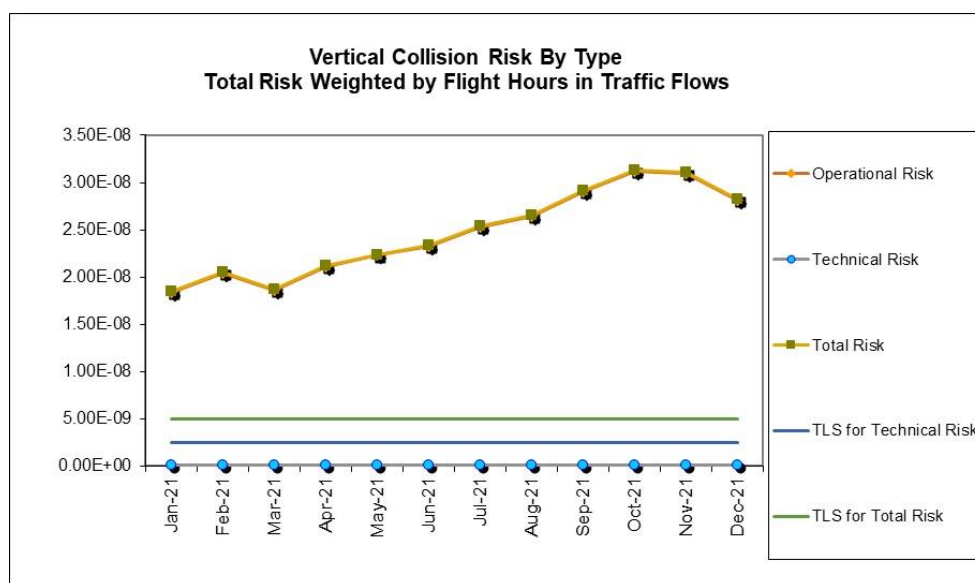
2.1 **Attachment A** contains the PARMO Vertical Safety Monitoring Report for January to December 2021.

### Executive Summary for Pacific Airspace

2.2 **Table 1** summarizes Pacific airspace RVSM technical, operational, and total risks. **Figure 1** presents collision risk estimate trends during the period from January 2021 to December 2021.

Pacific Airspace – estimated annual flying hours = 1,176,737.3 hours (note: estimated hours based on Dec 2021 traffic sample data)			
Source of Risk	Risk Estimation	TLS	Remarks
RASMAG 26 Total Risk	$22.04 \times 10^{-9}$	$5.0 \times 10^{-9}$	Above TLS
Technical Risk	$0.11 \times 10^{-9}$	$2.5 \times 10^{-9}$	Below Technical TLS
Operational Risk	$28.31 \times 10^{-9}$	-	-
Total Risk	$28.21 \times 10^{-9}$	$5.0 \times 10^{-9}$	<b>Above TLS</b>

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



**Figure 1:** Pacific Airspace RVSM Risk Estimate Trends

2.3 The largest contributors to the vertical collision risk estimate are reported LHD category E occurrences involving HCF and Oakland center. This specific set of reported LHDs account for 73 percent of the total risk estimate. The total vertical risk estimate without these category E reported LHDs would be  $7.7 \times 10^{-9}$  fapfh. In addition to the removal of the category E occurrences involving HCF and Oakland center, the two largest duration LHDs are also removed, yielding a vertical risk estimate of  $5.7 \times 10^{-9}$  fapfh.

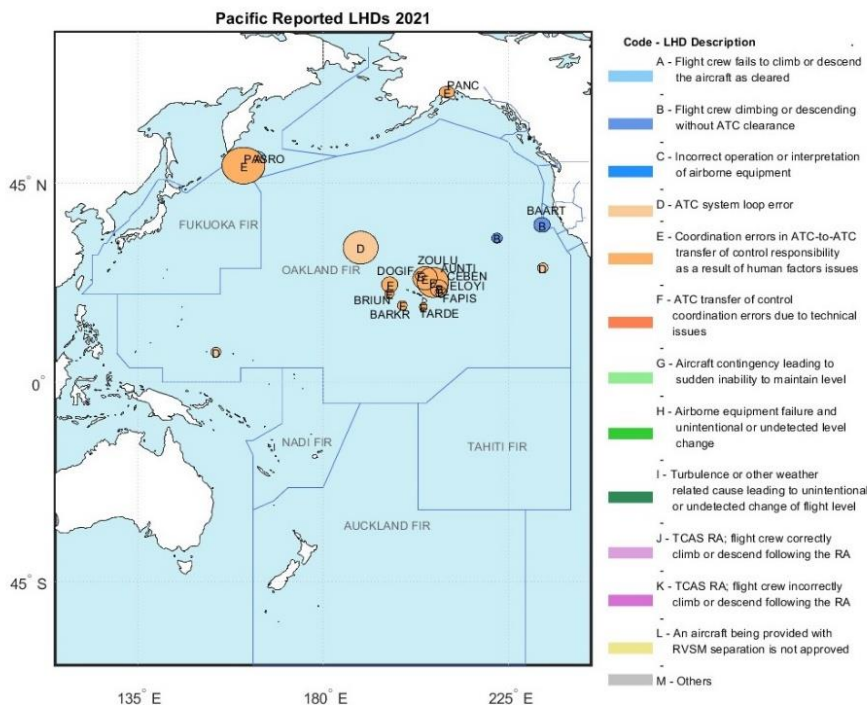
2.4 **Table 2** presents a summary of the LHD causes within Pacific airspace from January 2021 until December 2021.

Code	LHD Category Description	No.
A	Flight crew fails to climb or descend the aircraft as cleared	3
B	Flight crew climbing or descending without ATC clearance	7
C	Incorrect operation or interpretation of airborne equipment	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	44
F	ATC transfer of control coordination errors due to technical issues	1
G	Aircraft contingency leading to sudden inability to maintain level	0
H	Airborne equipment failure and unintentional or undetected level change	0
I	Turbulence or other weather related cause leading to unintentional or undetected change of flight level	6
J	TCAS resolution advisory; flight crew correctly climb or descend following the resolution advisory	0
K	TCAS resolution advisory; flight crew incorrectly climb or descend	0

Code	LHD Category Description	No.
	following the resolution advisory	
L	An aircraft being provided with RVSM separation is not RVSM approved	0
M	Others	1
Total		65

**Table 2:** Summary of LHD Causes within Pacific Airspace

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



**Figure 2:** Pacific Airspace – Risk Bearing LHD

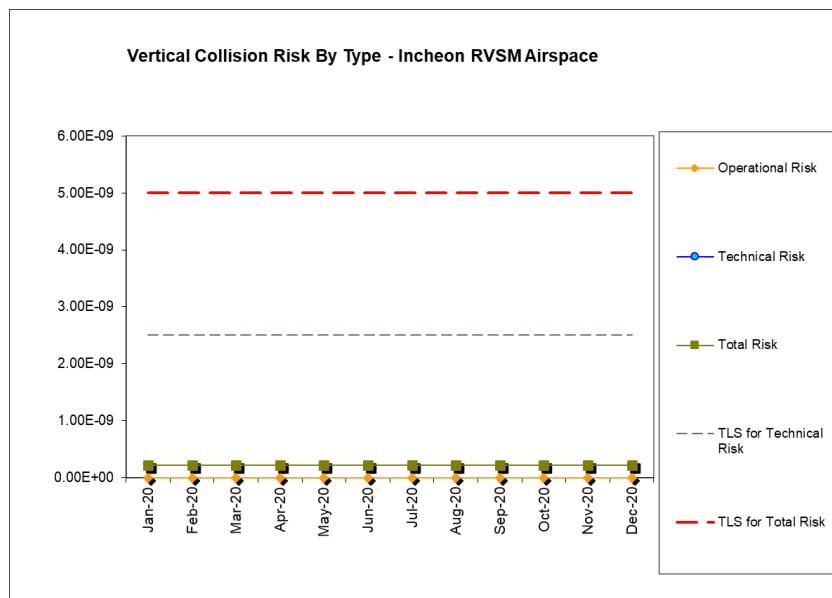
2.6 Mitigations for the high number of reported category E occurrences between Honolulu Control Facility (HCF) and Oakland center have been developed. A summary of the mitigations and planned automation system upgrade is provided in the attachment to this paper.

Executive Summary for a Portion of North East Asia Airspace

2.7 **Table 3** summarizes North East Asia airspace RVSM technical, operational, and total risks. **Figure 3** presents collision risk estimate trends during the period from January 2021 to December 2021.

North East Asia Airspace – estimated annual flying hours = 83,991.4 hours (note: estimated hours based on Dec 2021 traffic sample data)			
Source of Risk	Risk Estimation	TLS	Remarks
RASMAG 26 Total Risk	$0.23 \times 10^{-9}$	$5.0 \times 10^{-9}$	Below TLS
Technical Risk	$0.04 \times 10^{-9}$	$2.5 \times 10^{-9}$	Below Technical TLS
Operational Risk	$0.00 \times 10^{-9}$	-	-
Total Risk	<b><math>0.04 \times 10^{-9}</math></b>	$5.0 \times 10^{-9}$	<b>Below TLS</b>

**Table 3:** North East Asia Airspace RVSM Risk Estimates



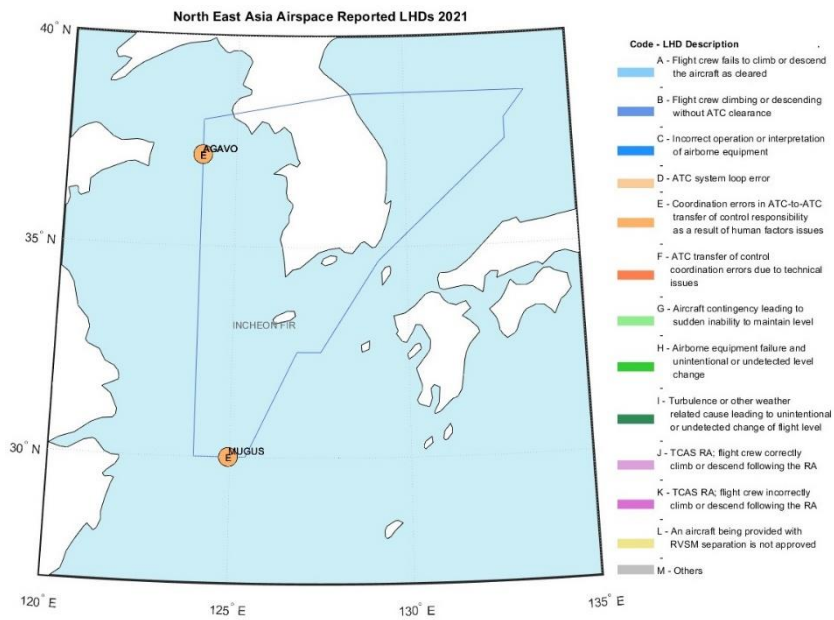
**Figure 3:** North East Asia Airspace RVSM Risk Estimate Trends

2.8 **Table 4** presents a summary of the LHD causes within North East Asia airspace from January 2021 until December 2021.

Code	LHD Category Description	No.
A	Flight crew fails to climb or descend the aircraft as cleared	0
B	Flight crew climbing or descending without ATC clearance	0
C	Incorrect operation or interpretation of airborne equipment	0
D	ATC system loop error	0
E	Coordination errors in the ATC -to-ATC transfer of control responsibility as a result of human factors issues	3
F	ATC transfer of control coordination errors due to technical issues	0
G	Aircraft contingency leading to sudden inability to maintain level	0
H	Airborne equipment failure and unintentional or undetected level change	0
I	Turbulence or other weather related cause leading to unintentional or undetected change of flight level	0
J	TCAS resolution advisory; flight crew correctly climb or descend following the resolution advisory	0
K	TCAS resolution advisory; flight crew incorrectly climb or descend following the resolution advisory	0
L	An aircraft being provided with RVSM separation is not RVSM approved	0
M	Others	0
Total		3

**Table 4:** Summary of LHD Causes within North East Asia Airspace

2.9 **Figure 4** provides the geographic location of risk bearing LHD reports within North East Asia Airspace during the assessment period.



**Figure 4:** North East Asia Airspace – Reported LHDs

2.10 There is a separate working paper to this meeting that highlights the AKARA airspace.

**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.

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## AIRSPACE SAFETY REVIEW OF THE RVSM IMPLEMENTATION IN PACIFIC AND NORTH EAST ASIA AIRSPACE January 2021 TO December 2021

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

### 1. Introduction

1.1 This report provides an airspace safety review of Reduced Vertical Separation Minimum (RVSM) airspace risk in the Anchorage, Auckland, Incheon, 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, Incheon, 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
Incheon	X
Nadi	X
Oakland	X
Tahiti	X

2.2 **Large Height Deviation (LHD).** A cumulative 12-month data set of LHD reports was used, covering January to December 2021. **Table 2** indicates those FIRs which submitted LHD reports including nil reports. All FIRs submitted LHD reports needed to compute the 2021 vertical operational risk estimates.

**Table 2.** Summary of LHD Reports submitted by FIRs

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

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

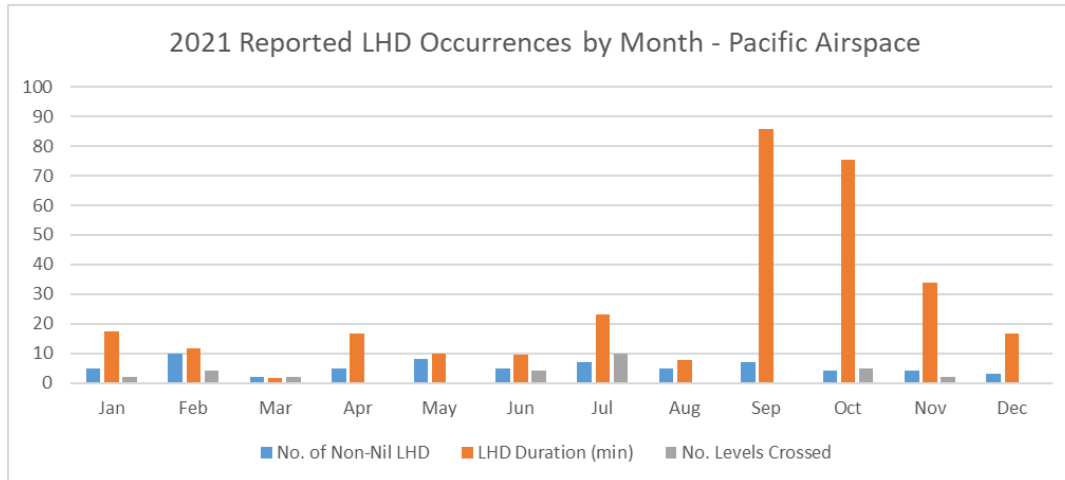
### 3. Summary of LHD Occurrences

#### 3.1 Pacific RVSM Airspace

3.2 **Table 3** and **Figure 1** summarize the number of LHD occurrences assessed and associated LHD duration (in minutes) or number of levels crossed by month from 1 January 2021 to 31 December 2021 inclusive for Pacific airspace.

**Table 3.** Summary of reported LHD occurrences and duration for Pacific RVSM airspace – Year 2021

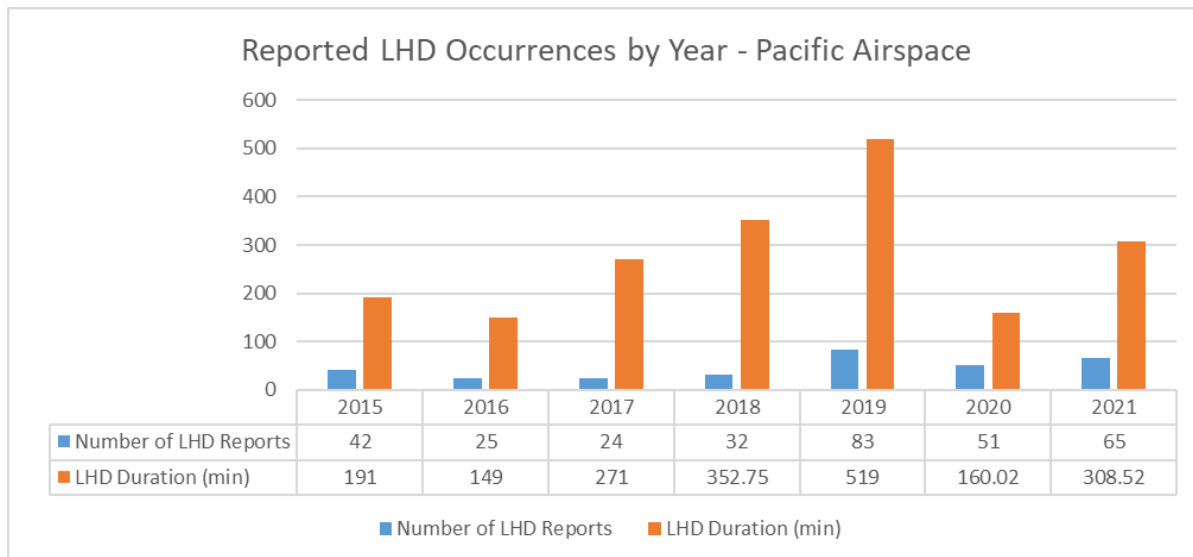
Month	No. of LHD	LHD Duration (min)	No. Levels Crossed
<b>2021</b>			
January	5	17.39	2
February	10	11.59	4
March	2	1.48	2
April	5	16.65	0
May	8	10.02	0
June	5	9.35	4
July	7	22.93	10
August	5	7.55	0
September	7	85.92	0
October	4	75.23	5
November	4	33.94	2
December	3	16.48	0
<b>Total</b>	<b>65</b>	<b>308.52</b>	<b>29</b>



**Figure 1.** Summary of LHD occurrences by month for Pacific RVSM airspace –2021

3.3 The reported LHDs for Pacific Airspace provided to the PARMO in 2021 indicated there were **308.52 minutes** of operation at an incorrect flight level. These data show an increase in both the number of LHD reports received and amount of time spent on incorrect flight levels from calendar year 2020. For comparison, the LHD reports provided to the PARMO within the recent seven-year period and associated time spent at incorrect flight level is provided in **Figure 2**.

3.4 The reported LHD durations and number of flight levels crossed are used to estimate vertical risk. The approximate locations of each reported LHD are needed so that the appropriate traffic flow characteristics can be applied to each event in the calculation of risk. **Table 4** provides the different Pacific traffic flows and the corresponding descriptions.



**Figure 2.** Numbers of LHD Reports Received and Associated LHD Duration

**Table 4.** Pacific Traffic Flows used for Vertical Collision Risk Estimation

Sub-Region of Pacific	Flow	Description of Flow
North Pacific	North Pacific (NOPAC)	North America west to Japan/Korea/beyond plus Japan/Korea to and from Alaska and beyond
	Central Pacific (CENPAC)	Japan/Korea/other Asian origins east to North America
	Central East Pacific (CEP)	North American mainland to and from Hawaii
	Hawaii/Japan (JPHAWA)	Japan/Korea to and from Hawaii
	Japan/Guam (JPGUAM)	Japan/Korea to and from Guam/Saipan/other proximate destinations
	Other (OTHER)	All other North Pacific flights not covered above
South Pacific and Pacific trans-equatorial	Australia/New Zealand/South Pacific States (AUSNZSP)	Australia to and from New Zealand; Australia to and from South Pacific island states; New Zealand to and from South Pacific states
	Nadi (NADI)	Fiji to and from all airports except those in Australia or New Zealand
	Australia-New Zealand/Japan (AUSNZJP)	Australia to and from Japan/Korea; New Zealand to and from Japan/Korea
	South Pacific (SOPAC)	Australia to and from airports in northern hemisphere; New Zealand to and from airports in northern hemisphere

3.5 An LHD event with a duration of 20 minutes or more is a long duration event. There were **three** reported long durations LHD events in 2021. For comparison, the number of long duration LHD reports received in 2018, 2019, and 2020 were six, five, and one, respectively.

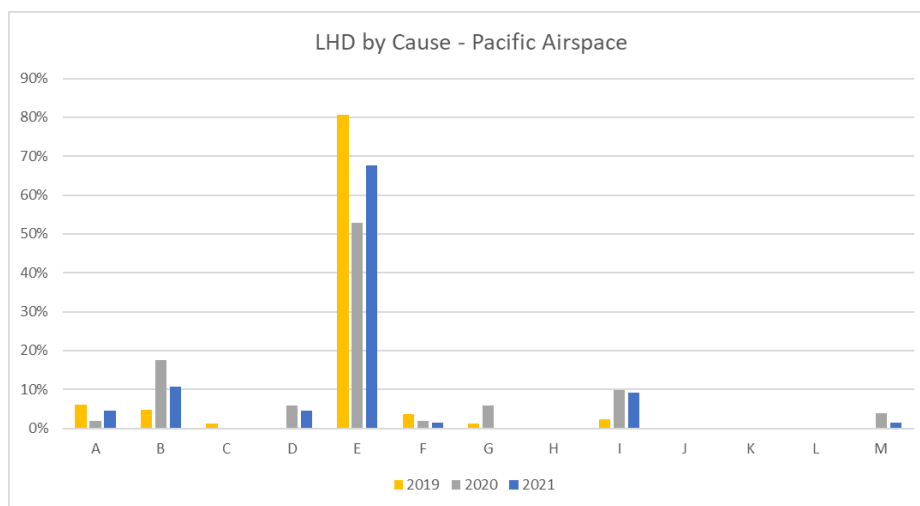
3.5.1 There was a reported LHD with duration of fifty-six minutes in September 2021. This occurrence took place in the North Pacific (NOPAC) area of Pacific airspace. The NOPAC contains traffic operating on fixed airways between North America and Asia. The primary cause of this occurrence was error in ATC-to-ATC transfer due to human factor issues. The receiving ATC unit's automation system did not receive a coordination message and therefore did not have a flight plan for the aircraft. There was an automation outage during the time of this occurrence, but there are procedures for coordination during outage periods. The scrutiny group estimated that the aircraft spent 56 minutes of travel time before the aircraft profile was entered into the automation system. There was information from both ATC units for this occurrence.

- 3.5.2 There was a reported LHD with fifty-nine minutes duration 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. 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.
- 3.5.3 There was a reported LHD with 23.9 minutes duration in November 2021. This occurrence took place within the Central East Pacific (CEP) traffic flow, this traffic flow contains aircraft operations travelling between North America and Hawaii. The primary cause of this occurrence was error in ATC-to-ATC transfer due to human factor issues. This reported occurrence is part of the grouped occurrences involving transfer errors between Honolulu Control Facility (HCF) and Oakland Oceanic FIR, these will be discussed later in the report.

3.6 **Table 5** and **Figure 3** summarize the number of LHD occurrences, the associated LHD duration (in minutes) and number of flight levels crossed without clearance, by LHD category from 1 January to 31 December 2021 inclusive for Pacific RVSM airspace. **Figure 4** provides a geographic chart with the approximate locations of the non-nil LHD reports.

3.7 Table 5 and Figure 3 show categories E and F, errors in ATC-to-ATC transfer are the top contributors to reported LHD occurrences during calendar year 2021. This is consistent with the previous calendar year. Figure 3 provides the observed trend in the numbers of reported LHDs by category over the current three-year period.

3.8 An increase in both the number of reported LHDs and duration spent at the unexpected/incorrect flight level was observed in 2021 compared to 2020.



**Figure 3.** Summary of LHD causes for Pacific RVSM airspace

**Table 5.** 12-month LHD reports by LHD category for Pacific RVSM airspace - 2021

<b>LHD Category Code</b>	<b>LHD Category Description</b>	<b>No of LHD Occurrences</b>	<b>LHD Duration (Min)</b>	<b>No. of Flight Levels Transitioned Without Clearance</b>
A	Flight crew failing to climb/descend the aircraft as cleared;	3	5	3
B	Flight crew climbing /descending without ATC clearance;	7	21	20
C	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.)	0	0	0
D	ATC system loop error; (e.g. ATC issues incorrect clearance or flight crew misunderstands clearance message);	3	70	0
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility as a result of human factors issues (e.g. late or non-existent coordination, incorrect time estimate/actual, flight level, ATS route etc not in accordance with agreed parameters);	44	212.52	0
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues;	1	0	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level (e.g. pressurization failure, engine failure);	0	0	0
H	Airborne equipment failure leading to unintentional or undetected change of flight level (e.g. altimetry errors)	0	0	0
I	Turbulence or other weather related causes	6	0	2
J	TCAS resolution advisory; flight crew correctly following the resolution advisory	0	0	0
K	TCAS resolution advisory; flight crew incorrectly following the resolution advisory	0	0	0
L	An aircraft being provided with RVSM separation is not RVSM approved (e.g. flight plan indicating RVSM approval but aircraft not approved, ATC misinterpretation of flight plan);	0	0	0
M	Other	1	0	4

<b>LHD Category Code</b>	<b>LHD Category Description</b>	<b>No of LHD Occurrences</b>	<b>LHD Duration (Min)</b>	<b>No. of Flight Levels Transitioned Without Clearance</b>
	<b>Totals</b>	<b>65</b>	<b>308.52</b>	<b>29</b>

3.9 The reported LHDs for 2021 included a large number of reports classified as category E for transfer errors between Honolulu Control Facility (HCF) and Oakland Oceanic FIR. The scrutiny review group informed PARMO these occurrences 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.

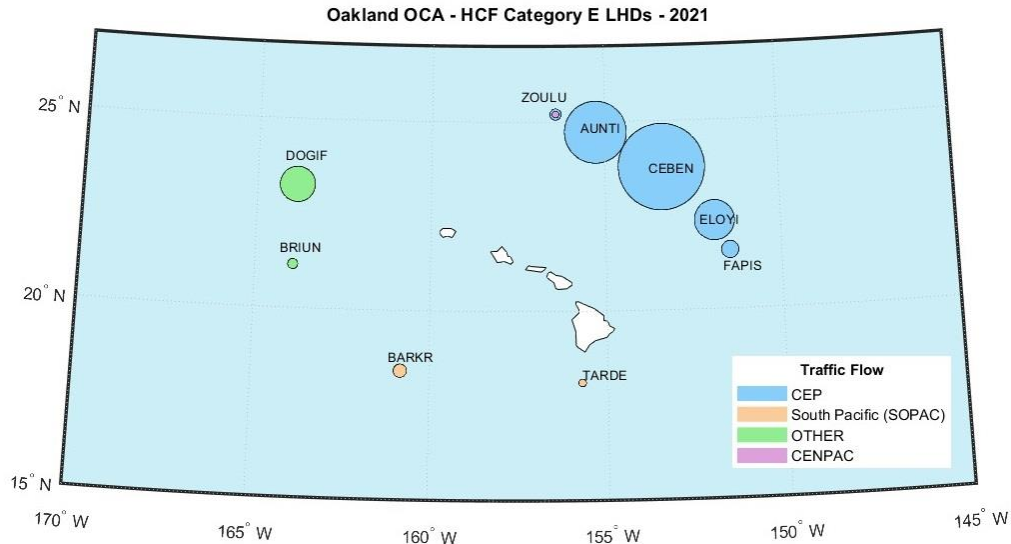
3.10 The available system data were examined for all of the reported occurrences involving HCF and Oakland center. The operational experts from Oakland center determined whether there was any unprotected time within Oakland Oceanic FIR for each occurrence. First, the actual boundary crossing time was noted. Next, the time stamp for an update to the aircraft profile in the Oakland automation system was noted. If the aircraft profile was updated prior to the boundary crossing, the occurrence is considered a reported prevention and has zero duration. If the aircraft profile was updated after the boundary crossing, the occurrence has a non-zero duration and unprotected time within Oakland Oceanic FIR.

3.11 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:

3.11.1 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.

3.11.2 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.

3.11.3 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.

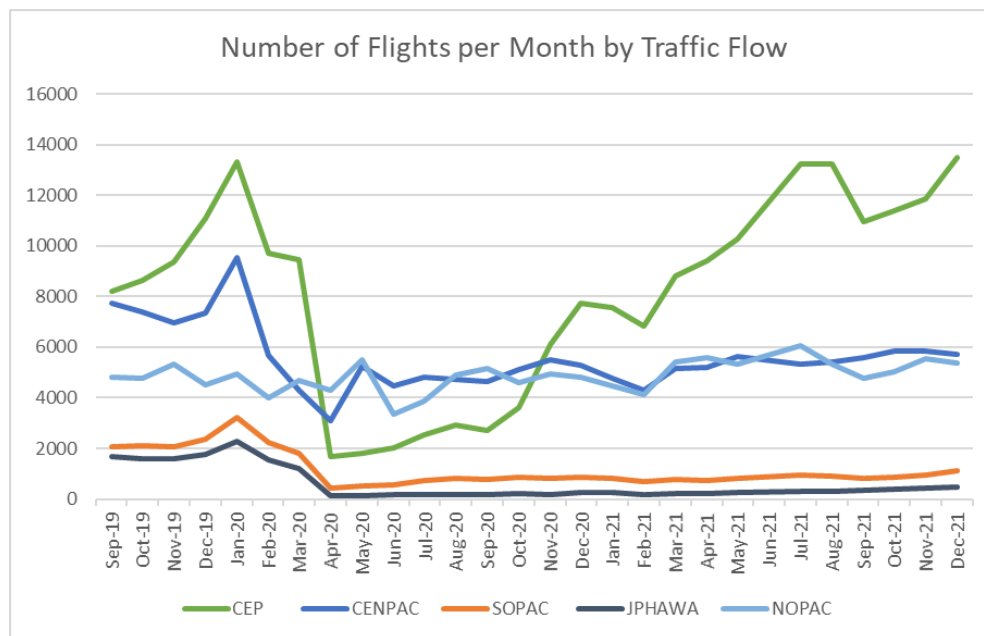


**Figure 4.** Reported LHDs transfer occurrences HCF – Oakland OCA (2021)

3.12 There were ninety-eight reported category E occurrences between HCF and Oakland center in calendar year 2021. This is an increase from the sixty-four reported category E occurrences received for calendar year 2020. Forty-one of the ninety-eight had a non-zero duration and are considered to be risk-bearing LHDs. The locations of these forty-one reported LHDs are shown in **Figure 4**. The different colors indicate which traffic flow was affected by the reported occurrence, determined by the city pair. The reported LHD with locations to the east of Hawaii affect the Central East Pacific (CEP) traffic are colored in blue. The other traffic flows affected by these transfer errors include South Pacific (SOPAC), Central Pacific (CENPAC) and Other traffic flows.

3.13 The number of reported LHDs categorized as E and F for all of Pacific airspace was forty-five. These occurrences represent more than half of all the reported LHDs for Pacific airspace in calendar year 2021. The reported LHD duration for category E and F reports is 68 percent of all reported LHD duration in calendar year 2021. Most of these occurrences were reported for aircraft transfers between HCF and Oakland center. There were four reported category E and F LHDs between different ATC facilities, these reports do not show a repeated pattern.

3.14 The methodology used to estimate vertical risk in Pacific airspace takes into account the location of the reported LHDs. The TSD is used to estimate flying hours and traffic densities separately for different areas within Pacific airspace. The identified traffic flows in Pacific airspace are provided in Table 4. For example, the CEP traffic flow contains aircraft operations travelling between North America and Hawaii. In 2021, the CEP traffic flow had the highest number of flight operations and flying hours compared to all other areas identified in Pacific airspace. The associated traffic flow for each event is based on the origin and destination city pair for the aircraft involved. **Figure 5** shows the numbers of flights observed by month for selected traffic flows, these data are sourced from Anchorage and Oakland oceanic centers. The CEP traffic flow (green line in Figure 5) shows the largest decrease in traffic from March 2020 to April 2020. The remaining traffic flows shown in Figure 5, including CENPAC, JPHAWA and SOPAC traffic flows, show decreases in traffic related to COVID-19 and continued traffic volume significantly below 2019 levels.



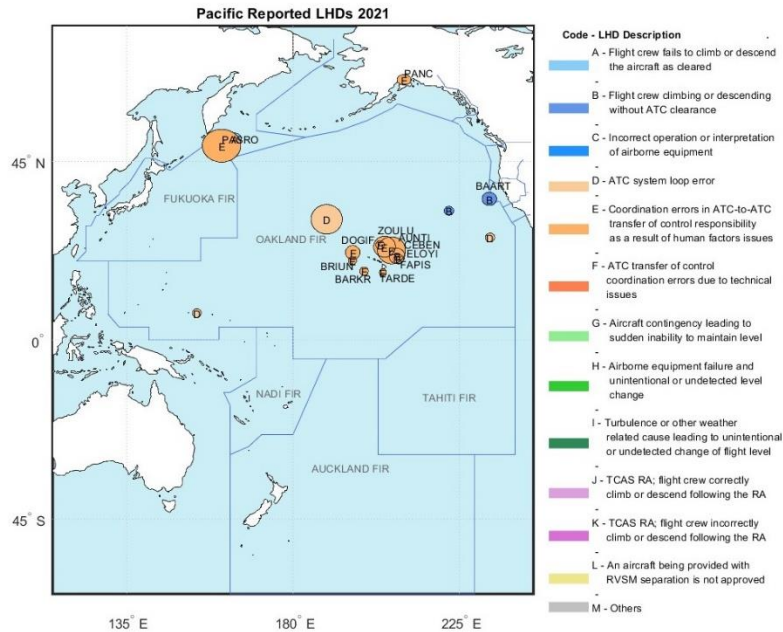
**Figure 5.** Number of Flights per Month by Traffic Flow

3.15 In 2021, the area of Pacific airspace with the largest reported LHD duration is the CEP traffic flow. This is the traffic flow that contains aircraft operations travelling between North America and Hawaii. **Figure 6** shows the approximate location and cause of all reported LHDs within Pacific airspace.

3.16 **Table 6** provides the LHD summary by Pacific traffic flow. The traffic flows listed in Table 6 are described earlier in Table 4. The values provided in Table 6 include the LHD duration in minutes by category code for each traffic flow. The fourth row in the table shows the CEP traffic flow has the largest LHD duration for 2021.

**Table 6.** Sum of LHD Duration (minutes) by Pacific Traffic Flow and LHD category - 2021

Traffic Flow	A	B	D	E	F	Total
AUSNZJP	0.0	0.0	0.0	0.0	0.0	0.0
AUSNZSP	0.0	0.0	0.0	0.0	0.0	0.0
CENPAC	0.0	0.0	0.0	0.4	0.0	0.4
CEP	0.0	21.0	0.0	128.64	0.0	149.64
JPHAWA	0.0	0.0	59.0	0.0	0.0	59.0
JPGUAM	0.0	0.0	0.0	0.0	0.0	0.0
NADI	0.0	0.0	0.0	0.0	0.0	0.0
NOPAC	5.0	0.0	7.0	56.0	0.0	61.0
OTHER	0.0	0.0	6.0	22.27	0.0	28.27
SOPAC	0.0	0.0	5.0	5.22	0.0	10.22
<b>Total</b>	<b>5.0</b>	<b>21.0</b>	<b>70.0</b>	<b>212.52</b>	<b>0.0</b>	<b>308.52</b>



**Figure 6.** Pacific RVSM airspace LHD locations - 2021

### 3.17 North East Asia RVSM Airspace

3.18 **Table 7** summarizes the number of LHD occurrences assessed and associated LHD duration (in minutes) or number of levels crossed by month from 1 January 2021 to 31 December 2021 inclusive for Incheon airspace. There were three reported LHDs in calendar year 2021, all three occurrences have zero duration and zero flight levels crossed without ATC clearance.

**Table 7.** Summary of reported LHD occurrences and duration for North East Asia RVSM airspace

Month-Year	No. of LHD	LHD Duration (min)	No. Levels Crossed
<b>2021</b>			
January	0	0	0
February	0	0	0
March	0	0	0
April	1	0	0
May	1	0	0
June	1	0	0
July	0	0	0
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0

Month-Year	No. of LHD	LHD Duration (min)	No. Levels Crossed
<b>2021</b>			
<b>Total</b>	2	0	0

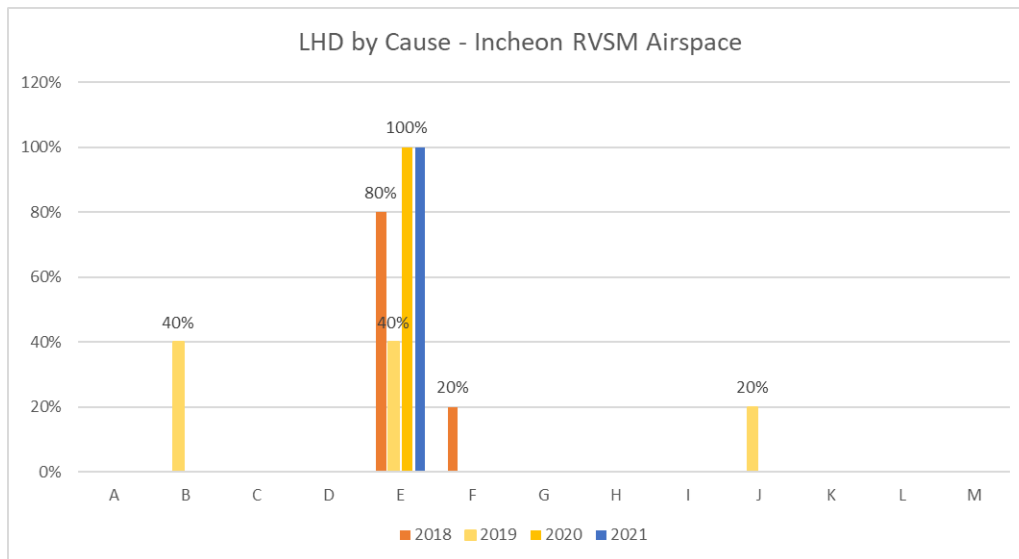
3.19 **Table 8** and **Figure 7** summarize the number of reported LHD occurrences by LHD category from 1 January 2021 to 31 December 2021 inclusive for Incheon RVSM airspace. Figure 7 provides the observed trends in reported LHD category codes for the recent three-year period, this summary does not include occurrences reported within the AKARA area.

3.20 **Figure 8** shows the locations of the reported LHDs occurrences. The reported LHDs for the AKARA corridor are not included in this analysis. The reported occurrences for the AKARA corridor airspace are contained in a separate working paper to this meeting.

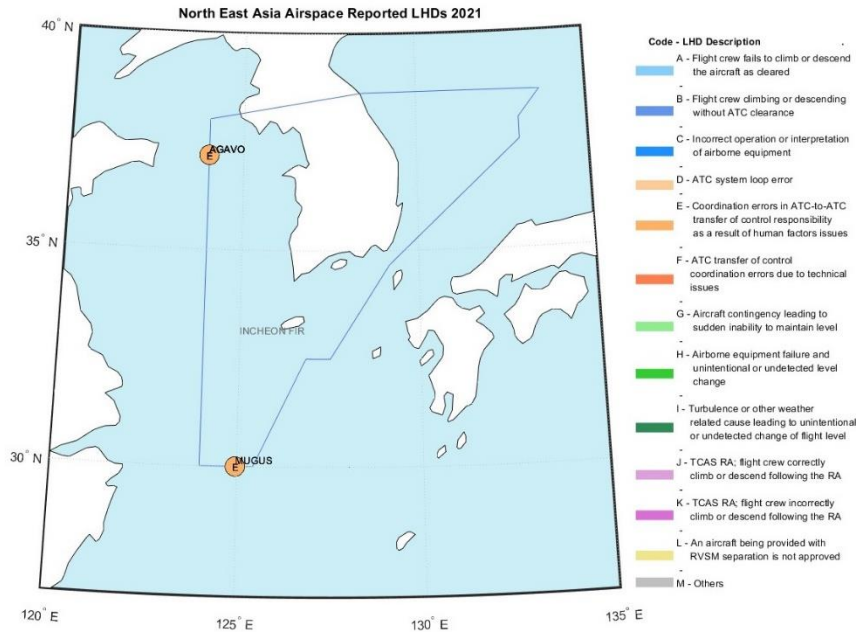
**Table 8.** LHD Summary by category for North East Asia RVSM airspace

LHD Category Code	LHD Category Description	No of LHD Occurrences	LHD Duration (Min)	No. of Flight Levels Transitioned Without Clearance
A	Flight crew failing to climb/descend the aircraft as cleared;	0	0	0
B	Flight crew climbing /descending without ATC clearance;	0	0	0
C	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.)	0	0	0
D	ATC system loop error; (e.g. ATC issues incorrect clearance or flight crew misunderstands clearance message);	0	0	0
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility as a result of human factors issues (e.g. late or non-existent coordination, incorrect time estimate/actual, flight level, ATS route etc not in accordance with agreed parameters);	3	0	0
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues;	0	0	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level (e.g. pressurization failure, engine failure);	0	0	0

LHD Category Code	LHD Category Description	No of LHD Occurrences	LHD Duration (Min)	No. of Flight Levels Transitioned Without Clearance
H	Airborne equipment failure leading to unintentional or undetected change of flight level (e.g. altimetry errors)	0	0	0
I	Turbulence or other weather related causes	0	0	0
J	TCAS resolution advisory; flight crew correctly following the resolution advisory	0	0	0
K	TCAS resolution advisory; flight crew incorrectly following the resolution advisory	0	0	0
L	An aircraft being provided with RVSM separation is not RVSM approved (e.g. flight plan indicating RVSM approval but aircraft not approved, ATC misinterpretation of flight plan);	0	0	0
M	Other	0	0	0
	<b>Totals</b>	<b>3</b>	<b>0</b>	<b>0</b>



**Figure 7.** Summary of LHD causes for Incheon RVSM airspace – 2021



**Figure 8.** Locations of the Reported LHD occurrences - 2021

#### 4. Risk Assessment and Safety Oversight

##### 4.1 Pacific RVSM airspace

##### 4.2 Collision Risk Model (CRM) Parameters

4.3 The value of the parameters in the CRM used to estimate risk in Pacific RVSM airspace, are summarized in **Table 9**. Other collision risk model parameters that vary by traffic flow include aircraft size, occupancy values, and flying hours. These parameters are shown in **Table 10** by traffic flow. Table 4 contains a listing and description for each traffic flow.

**Table 9.** Estimates of the parameters in the CRM for Pacific RVSM airspace

Parameter	Description	Value
$ \overline{\Delta V} $	Average relative same-direction speed	13 Knots
$ \overline{V} $	Average aircraft speed	480 knots
$ \overline{y'} $	Average relative cross-track speed	5 knots
$ \overline{z'} $	Average relative vertical speed during loss of vertical separation	1.5 knots
$P_z(0)$	Probability two aircraft at the same nominal level are in vertical overlap	0.42
$P_z(1000)$	Probability two aircraft nominally separated by 1 000 ft are in vertical overlap	$4.68 \times 10^{-9}$

**Table 10.** Vertical 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)	Same Direction Vertical Occupancy, $E_z(\text{Same})$	Opposite Direction Vertical Occupancy, $E_z(\text{Opp})$
NOPAC	238,771.3	20.29%	0.037	0.034	0.010	0.428	0.000
CENPAC	310,386.1	26.38%	0.037	0.035	0.010	0.327	0.088
CEP	461,989.7	39.26%	0.026	0.023	0.007	1.943	0.015
JPHAWA	20,000.0	1.70%	0.033	0.031	0.009	0.035	0.004
JPGUAM	6,000.0	0.51%	0.025	0.023	0.008	0.000	0.000
OTHER	12,786.4	1.09%	0.030	0.027	0.008	0.009	0.005
AUSNZSP	39,000.0	3.31%	0.025	0.023	0.007	0.013	0.031
NADI	15,000.0	1.27%	0.031	0.030	0.009	0.021	0.006
AUSNZJP	15,584.8	1.32%	0.034	0.033	0.009	0.013	0.037
SOPAC	57,218.9	4.86%	0.034	0.033	0.009	0.065	0.061
<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>		

4.4 **Risk Estimation Results.** The results for the technical, operational, and total risk for the RVSM airspace are detailed in **Table 11**. The technical risk meets the agreed target level of safety (TLS) value of no more than  $2.5 \times 10^{-9}$  fatal accidents per flight hour due to the loss of a correctly established vertical separation standard of 1,000 ft and to all causes. **The operational and weighted total risk exceeds the specified TLS value** for these components of  $5.0 \times 10^{-9}$  fapfh.

**Table 11.** Pacific Airspace 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>			
Source of Risk	Risk Estimation	TLS	Remarks
<i>RASMAG 26 Total Risk</i>	$22.04 \times 10^{-9}$	$5.0 \times 10^{-9}$	<i>Above TLS</i>
Technical Risk	$0.11 \times 10^{-9}$	$2.5 \times 10^{-9}$	Below Technical TLS
Operational Risk	$28.31 \times 10^{-9}$	-	-
Total Risk	<b><math>28.21 \times 10^{-9}</math></b>	$5.0 \times 10^{-9}$	<b>Above TLS</b>

4.5 **Figure 9** presents the trends of collision risk estimates for each month using the appropriate cumulative 12-month data set of LHD reports. The largest contributors to the vertical collision risk estimate are the reported LHD category E occurrences involving HCF and Oakland center. This specific set of reported LHDs account for 73 percent of the total risk estimate. The total vertical risk estimate without these category E reported LHDs would be  $7.7 \times 10^{-9}$  fapfh. In addition to the removal of the category E occurrences involving HCF and Oakland center, the two largest duration LHDs (described in paragraphs 3.5.1 and 3.5.2) are also removed, yielding a vertical risk estimate of  $5.7 \times 10^{-9}$  fapfh.

4.6 The increase in the vertical risk estimate is directly related to the increase in the time spent at unexpected flight levels.

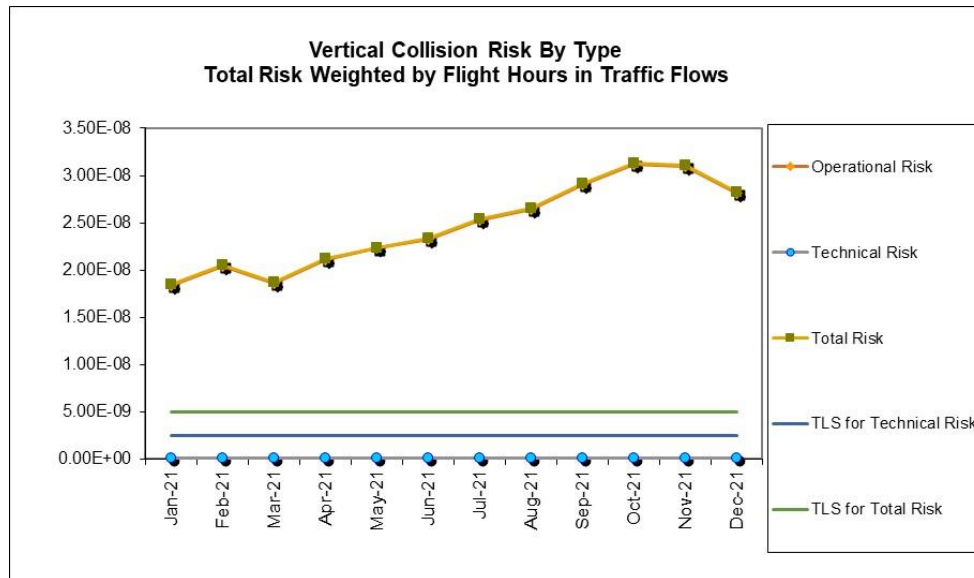


Figure 9. Trends of Risk Estimates for Pacific RVSM Airspace

#### 4.7 North East Asia RVSM airspace

#### 4.8 Collision Risk Model (CRM) Parameters

4.9 The value of the parameters in the CRM used to estimate risk in North East Asia RVSM airspace, are summarized in **Table 12**.

**Table 12.** Estimates of the parameters in the CRM for North East Asia RVSM airspace

Parameter	Description	Value
$\lambda_x$	Average aircraft length	0.034 NM
$\lambda_y$	Average aircraft wingspan	0.031 NM
$\lambda_z$	Average aircraft height	0.009 NM
$ \Delta V $	Average relative same-direction speed	38.3 Knots
$ V $	Average aircraft speed	480 knots
$ \dot{y} $	Average relative cross-track speed	5 knots
$ \dot{z} $	Average relative vertical speed during loss of vertical separation	1.5 knots
$P_z(0)$	Probability two aircraft at the same nominal level are in vertical overlap	0.42
$P_z(1000)$	Probability two aircraft nominally separated by 1 000 ft are in vertical overlap	$4.68 \times 10^{-9}$
$E_z(\text{Same})$	Same direction vertical occupancy value	0.2410
$E_z(\text{Opp})$	Opposite direction vertical occupancy value	0.0153

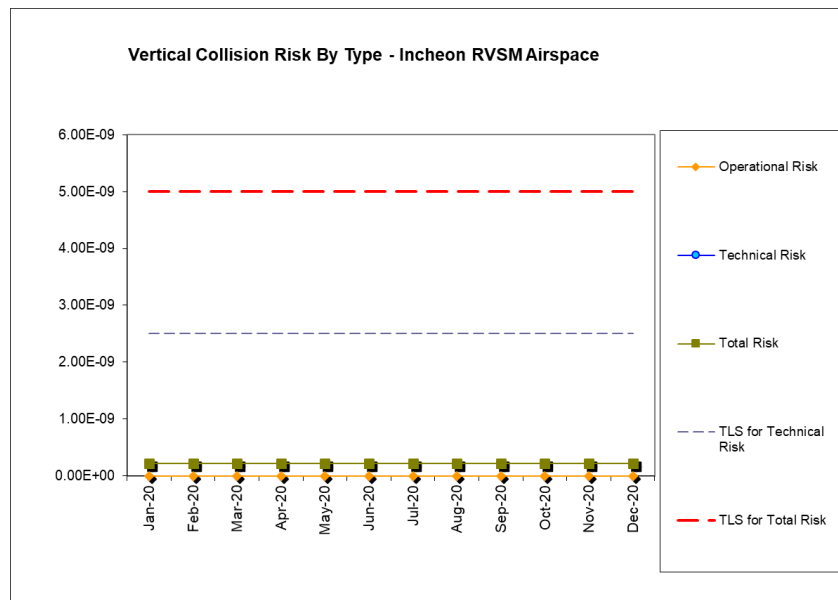
4.10 **Risk Estimation Results.** The results for the technical, operational, and total risk for the RVSM implementation are detailed in **Table 13**. The technical risk meets the agreed TLS value of no more than  $2.5 \times 10^{-9}$  fatal accidents per flight hour due to the loss of a correctly established vertical separation

standard of 1,000 ft and to all causes. **The operational and weighted total risk meets the specified TLS value** for these components of  $5.0 \times 10^{-9}$  fapfh.

4.11 **Figure 10** presents the trends of collision risk estimates for each month using the appropriate cumulative 12-month data set of LHD reports.

**Table 13.** North East Asia RVSM Airspace Risk Estimates

<b>North East Asia Airspace – estimated annual flying hours = 83,991.4 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 26 Total Risk</i>	$0.23 \times 10^{-9}$	$5.0 \times 10^{-9}$	<i>Below TLS</i>
Technical Risk	$0.04 \times 10^{-9}$	$2.5 \times 10^{-9}$	Below Technical TLS
Operational Risk	$0.00 \times 10^{-9}$	-	-
<b>Total Risk</b>	<b><math>0.04 \times 10^{-9}</math></b>	$5.0 \times 10^{-9}$	<b>Below TLS</b>



**Figure 10.** Trends of Risk Estimates for North East Asia RVSM Airspace