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Agenda Item 2: Review of the Results of Large Height Deviation (LHD)
2.3 Results of the assessment project for safety in RVSM airspace for the CAR and SAM Regions

MEXICO AIRSPACE VERTICAL SAFETY MONITORING REPORT – 2019

(Presented by United States)

EXECUTIVE SUMMARY

This Information Paper provides the vertical safety monitoring report for the continued-safe use of the Reduced Vertical Separation Minimum (RVSM) in Mexico Airspace. The safety assessment has been conducted according to the methodology endorsed by the International Civil Aviation Organization (ICAO). This work makes use of large height deviation (LHD) reports and traffic sample data (TSD) provided by Mexico to the NAARMO for calendar year 2019.

The purpose of this report is to compare actual performance to safety goals related to continued use of the RVSM in Mexico airspace. This report contains a summary of large height deviation reports received by the NAARMO for the calendar year 2019. There are fifty (50) reported large height deviations in calendar year 2019 for Mexico airspace. This report also contains an estimate of the vertical collision risk. The vertical collision risk estimate for Mexico airspace meets the target level of safety (TLS) value of 5.0 × 10-9 fatal accidents per flight hour.

Strategic Objectives:	• Safety
References:	• Reports of Large Height Deviations (LHD) in 2019 • December 2019 Mexican Traffic Sample Data (TSD) • FAA Traffic Flow Management System (TFMS) • ICAO Doc 9574 • ICAO Doc 9937

1. Introduction

1.1 The Dirección General de Aeronáutica Civil (DGAC Mexico) implemented the Reduced Vertical Separation Minimum (RVSM) between flight level 290 and flight level 410, inclusive, in all sovereign and delegated Mexico airspace on January 20, 2005. By mutual agreement, along with Mexico, Canada, and the United States, the North American Aviation Trilateral States, implemented the RVSM simultaneously on the same date in all North American airspace.

1.2. The North American Approvals Registry and Monitoring Organization (NAARMO), a service provided by the FAA Technical Center, fulfills the role of regional monitoring agency (RMA) for the continued-safe use of the RVSM in North American airspace.

1.3. This report covers the calendar year 2019. Within this report, the reader will find a summary of the large height deviation (LHD) reports received by the NAARMO and the corresponding vertical collision risk estimate. A new methodology was applied to the 2019 traffic data which considers the differences in traffic volumes and patterns. The resulting vertical risk estimate includes portions of the Gulf of Mexico (GOMEX), Mexico domestic, and Mexico offshore/oceanic airspace.

2. Traffic Sample Data

2.1 The NAARMO received a December 2019 traffic sample data (TSD) for Mexico airspace. These data included flight observations from four area control centers (ACCs) – Mexico (MMEX), Monterrey (MMTY), Mazatlán (MMZT), and Mérida (MMID). The information provided for each flight operation includes the date, aircraft call sign, aircraft registration mark, aircraft type, origin airport, destination airport, and aircraft position information.

2.2 In addition to the TSD received from the four ACCs, the NAARMO has access to the Federal Aviation Administration’s (FAA’s) Traffic Flow Management System (TFMS), which includes aircraft observations in Mexico airspace. Each traffic movement record within the TFMS data sample contains the date, time, latitude, longitude, flight level, aircraft flight identification, aircraft type, origin airport and the destination airport. The TFMS data contain frequent position estimates for each flight – a position estimate is provided approximately once a minute. **Figure 2-1** presents the aircraft positions provided in the TFMS data for 27 December 2019.

2.3 The different colors displayed in Figure 2-1 represent traffic flow sections of the operations observed in the TFMS data. The observed aircraft positions are placed into one of three traffic flows. Portions of an individual flight operation might appear in multiple traffic flows.

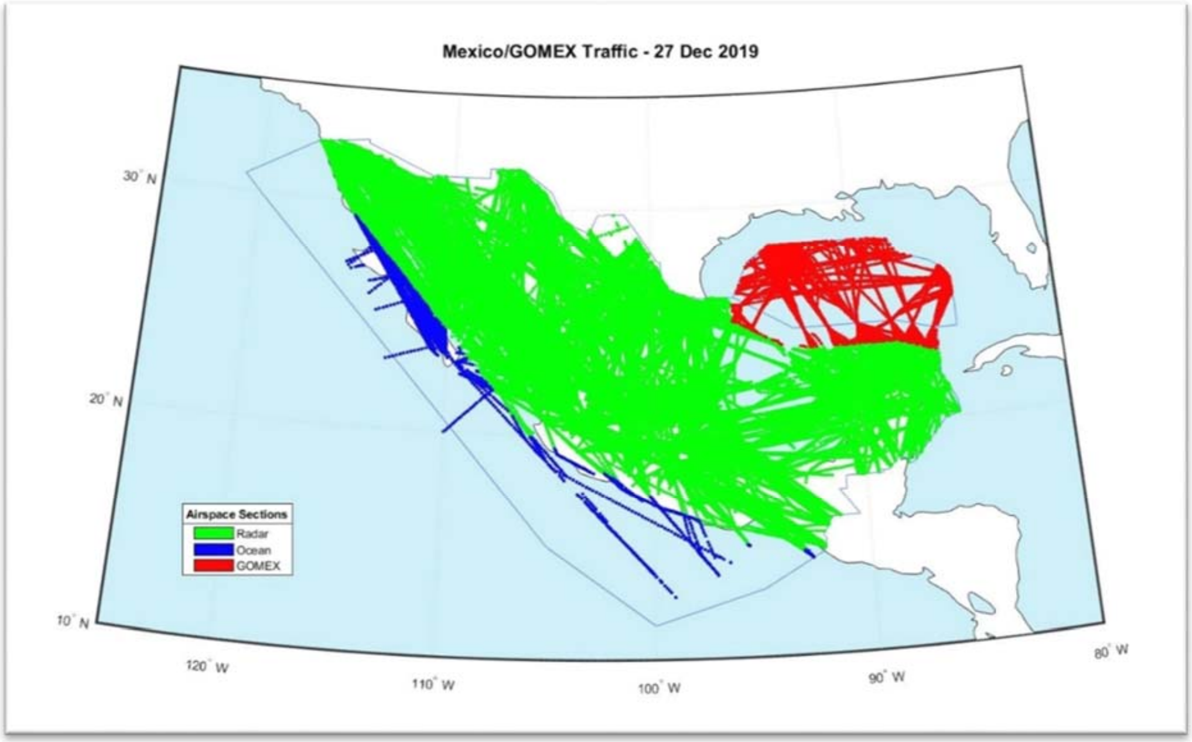

Figure 2-1. Aircraft Position Data Provided in TFMS – 27 December 2019

2.4 The three traffic flows are based on traffic volume and patterns. The three traffic flows include a portion of the Gulf of Mexico (GOMEX), Mexico offshore/oceanic, and Mexico domestic airspace. These three traffic flows are described below.

2.5 The portion of GOMEX airspace considered in this analysis includes flight segments that cross the Houston Oceanic CTA/FIR - Mexico FIR/CTA boundary over the Gulf of Mexico. In Figure 2-1, these are the operations shown in the color **red**.

2.6 Mexico offshore/oceanic airspace refers to observed air traffic over the Pacific Ocean where radar surveillance may not be available. In Figure 2-1, these operations are shown in the color **blue**.

2.7 Mexico domestic airspace includes all aircraft operations not considered GOMEX or oceanic airspace. Radar surveillance is available in domestic airspace, in Figure 2-1 these aircraft positions are shown in the color **green**.

2.8 **Figure 2-2** shows the number of flights by day in the TFMS data for December 2019. The horizontal blue line represents the average number of flight operations per day observed in the data sample. The average number of flight operations per day observed in the TFMS data is 3,301 flights per day. This value is slightly higher than observed in the 2018 data; **Table 2-1** shows the trend. The increase observed in 2019 can be attributed to the inclusion of the operations within Houston Oceanic CTA/FIR.

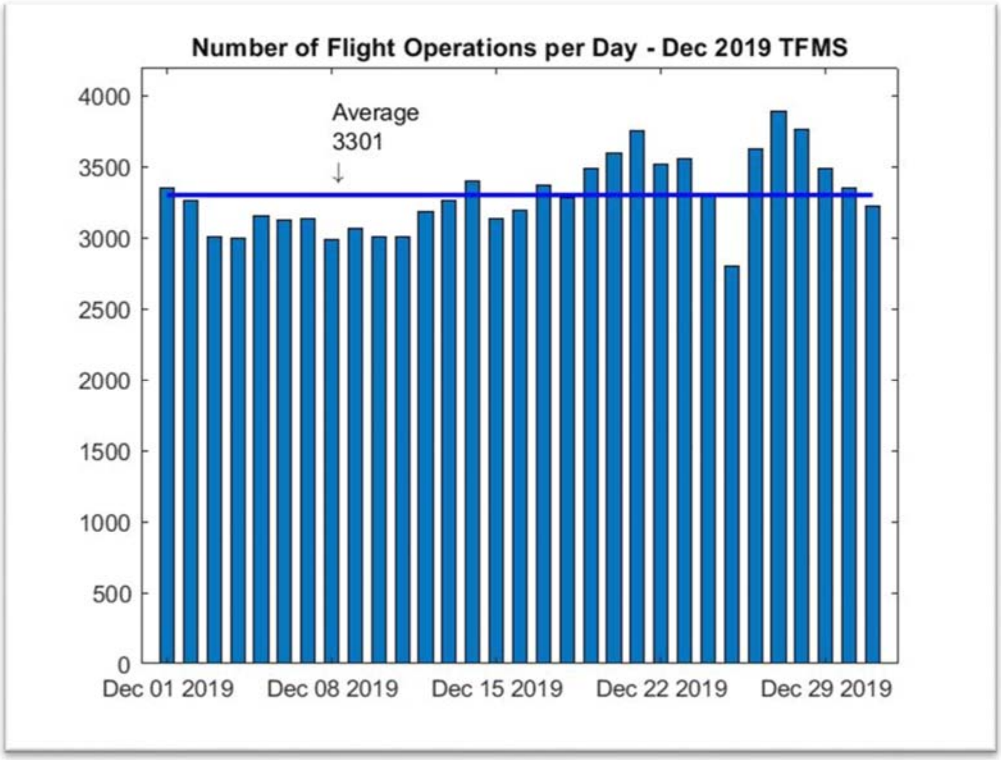

Figure 2-2. Number of Flight Operations Observed by Day - TFMS December 2019

Table 2-1. Average Number of Daily Flight Operations - Trend

Month-Year	Average Number of Daily Flight Operations
December 2015	2,378
December 2016	2,508
December 2017	2,732
December 2018	2,710
December 2019	3,301

3. RVSM Airspace Audit

3.1 The December 2019 TSD received from Mexico for the MMEX, MMTY, MMZT, and MMID ACCs are used to identify the operations operating within RVSM airspace. These data total approximately 126,700 operations in the month of December 2019.

3.2 The December 2019 TSD for Mexico airspace was compared with the collective approvals database as of 2 June 2020 to determine the approval status of each observed operation. The operations for which no approval or an expired approval is found are identified for further verification. **Table 3-1** provides a summary of the results of the Mexico RVSM Airspace Audit following the initial verification process. The results are listed alphabetically by the State of the Operator/Registry. This list contains 179 civilian non-approved operations from seven different States observed within RVSM airspace in Mexico. This number of non-approved operations is similar to the number observed in 2018.

3.3 Sixty-eight aircraft registrations identified as non-approved in the December 2018 TSD were also observed as non-approved in 2019. These sixty-eight aircraft registrations observed as non-approved in the 2018 and 2019 traffic samples are highlighted in **yellow** in **Table 3-1**. There are several aircraft registrations observed once or twice in the December 2019 traffic sample. More frequent traffic samples, such as quarterly, would help to identify anomalies in the results. The NAARMO suggests that traffic sample data for the months of March, June, September and December each calendar year be provided in order to remove possible anomalies and better identify aircraft registrations filing 'W' in item 10 but operating without RVSM approval.

Table 3-1. Mexico RVSM Airspace Audit – 2019

State of Operator/Registry	Aircraft Registration	RMA	Count of Observations
Canada	CFTUN	NAARMO	2
Ecuador	HCCUH	CARSAMMA	2
Guatemala	**TGDAE**	**CARSAMMA**	**3**
Guatemala	TGRIE	CARSAMMA	2
Mexico	**XAAMI**	**NAARMO**	**26**
Mexico	**XAARB**	**NAARMO**	**1**
Mexico	**XAARR**	**NAARMO**	**2**
Mexico	**XABNG**	**NAARMO**	**2**
Mexico	**XABZN**	**NAARMO**	**2**
Mexico	XACDM	NAARMO	2
Mexico	XACHF	NAARMO	2
Mexico	XACRG	NAARMO	5
Mexico	XACYP	NAARMO	4
Mexico	XADAK	NAARMO	10
Mexico	**XADHM**	**NAARMO**	**2**
Mexico	**XADIJ**	**NAARMO**	**6**
Mexico	**XADON**	**NAARMO**	**2**
Mexico	XADRG	NAARMO	9
Mexico	XAECA	NAARMO	62
Mexico	XAEME	NAARMO	45
Mexico	XAFLY	NAARMO	5
Mexico	**XAGDQ**	**NAARMO**	**2**
Mexico	XAGGB	NAARMO	26
Mexico	XAGIN	NAARMO	2
Mexico	XAGTR	NAARMO	2
Mexico	XAGTT	NAARMO	2
Mexico	**XAHCR**	**NAARMO**	**1**
Mexico	**XAHEL**	**NAARMO**	**6**
Mexico	**XAJAO**	**NAARMO**	**2**
Mexico	XAKAD	NAARMO	8

State of Operator/Registry	Aircraft Registration	RMA	Count of Observations
Mexico	XALON	NAARMO	18
Mexico	**XALRM**	**NAARMO**	**6**
Mexico	XAMAX	NAARMO	4
Mexico	XAMCF	NAARMO	27
Mexico	XAMLO	NAARMO	2
Mexico	XAMLS	NAARMO	4
Mexico	XAMMN	NAARMO	1
Mexico	XAMRA	NAARMO	3
Mexico	**XAOFM**	**NAARMO**	**12**
Mexico	XAOLA	NAARMO	8
Mexico	**XAOLI**	**NAARMO**	**16**
Mexico	**XAOOI**	**NAARMO**	**3**
Mexico	**XAPMH**	**NAARMO**	**2**
Mexico	XAPOX	NAARMO	23
Mexico	**XAQLO**	**NAARMO**	**1**
Mexico	XAQPL	NAARMO	2
Mexico	**XARAB**	**NAARMO**	**3**
Mexico	XARAY	NAARMO	1
Mexico	**XARED**	**NAARMO**	**4**
Mexico	**XARFB**	**NAARMO**	**5**
Mexico	XARIU	NAARMO	2
Mexico	**XARJT**	**NAARMO**	**29**
Mexico	**XASOF**	**NAARMO**	**14**
Mexico	**XASRD**	**NAARMO**	**4**
Mexico	**XASSE**	**NAARMO**	**24**
Mexico	XASUS	NAARMO	1
Mexico	XATAP	NAARMO	2
Mexico	**XAUBI**	**NAARMO**	**1**
Mexico	**XAUFF**	**NAARMO**	**11**
Mexico	**XAUSF**	**NAARMO**	**2**
Mexico	**XAUWF**	**NAARMO**	**24**
Mexico	**XAUZF**	**NAARMO**	**2**
Mexico	XAVBC	NAARMO	4
Mexico	**XAVCM**	**NAARMO**	**17**
Mexico	XAVCY	NAARMO	24
Mexico	XAVDA	NAARMO	6
Mexico	XAVDF	NAARMO	4
Mexico	XAVDK	NAARMO	5
Mexico	XAVDL	NAARMO	8

State of Operator/Registry	Aircraft Registration	RMA	Count of Observations
Mexico	XAVDP	NAARMO	3
Mexico	XAVDT	NAARMO	3
Mexico	XAVDU	NAARMO	42
Mexico	XAVFJ	NAARMO	1
Mexico	XAWSJ	NAARMO	2
Mexico	**XAXTR**	**NAARMO**	**11**
Mexico	**XAYCC**	**NAARMO**	**12**
Mexico	XAZAP	NAARMO	1
Mexico	XBAAG	NAARMO	5
Mexico	XBABD	NAARMO	2
Mexico	XBACS	NAARMO	2
Mexico	XBAJA	NAARMO	1
Mexico	XBBPS	NAARMO	2
Mexico	**XBCAF**	**NAARMO**	**6**
Mexico	XBCCG	NAARMO	2
Mexico	**XBCRL**	**NAARMO**	**7**
Mexico	**XBDGA**	**NAARMO**	**7**
Mexico	**XBFCR**	**NAARMO**	**2**
Mexico	XBFFF	NAARMO	6
Mexico	XBFIR	NAARMO	10
Mexico	XBGDJ	NAARMO	11
Mexico	XBGTT	NAARMO	2
Mexico	XBIXT	NAARMO	1
Mexico	**XBJHV**	**NAARMO**	**1**
Mexico	XBJJS	NAARMO	1
Mexico	XBJSC	NAARMO	4
Mexico	**XBJTG**	**NAARMO**	**1**
Mexico	XBKWN	NAARMO	6
Mexico	**XBMNV**	**NAARMO**	**4**
Mexico	**XBMSZ**	**NAARMO**	**3**
Mexico	XBMXK	NAARMO	2
Mexico	XBMYO	NAARMO	3
Mexico	XBNNA	NAARMO	1
Mexico	**XBNPF**	**NAARMO**	**24**
Mexico	XBNRX	NAARMO	1
Mexico	**XBNVE**	**NAARMO**	**2**
Mexico	**XBNVN**	**NAARMO**	**2**
Mexico	**XBNXX**	**NAARMO**	**9**
Mexico	**XBNZS**	**NAARMO**	**13**

State of Operator/Registry	Aircraft Registration	RMA	Count of Observations
Mexico	XBOAP	NAARMO	7
Mexico	**XBODW**	**NAARMO**	**13**
Mexico	**XBOTZ**	**NAARMO**	**3**
Mexico	XBOYM	NAARMO	1
Mexico	XBOZA	NAARMO	4
Mexico	XBOZH	NAARMO	4
Mexico	**XBPEB**	**NAARMO**	**2**
Mexico	**XBPGP**	**NAARMO**	**2**
Mexico	**XBPGQ**	**NAARMO**	**3**
Mexico	**XBPGY**	**NAARMO**	**2**
Mexico	**XBPHP**	**NAARMO**	**4**
Mexico	**XBPND**	**NAARMO**	**5**
Mexico	XBPNK	NAARMO	1
Mexico	XBPNQ	NAARMO	1
Mexico	XBPVI	NAARMO	2
Mexico	XBPVL	NAARMO	3
Mexico	XBPYV	NAARMO	5
Mexico	XBPYY	NAARMO	4
Mexico	**XBRAY**	**NAARMO**	**9**
Mexico	XBRBV	NAARMO	1
Mexico	**XBRGB**	**NAARMO**	**6**
Mexico	XBRJT	NAARMO	2
Mexico	**XBRSC**	**NAARMO**	**2**
Mexico	XBRUA	NAARMO	3
Mexico	XBSGT	NAARMO	4
Mexico	XBUAD	NAARMO	2
Mexico	XBULG	NAARMO	1
Mexico	XBUNA	NAARMO	2
Mexico	XBUOC	NAARMO	25
Mexico	XBVDA	NAARMO	1
Mexico	**XBVFJ**	**NAARMO**	**4**
Mexico	XBVSA	NAARMO	6
Mexico	**XBVXS**	**NAARMO**	**6**
Mexico	**XCBJG**	**NAARMO**	**28**
Panama	HP1376	CARSAMMA	2
Panama	HP1810DAE	CARSAMMA	5
Panama	HP1910DAE	CARSAMMA	8
Panama	HP2010DAE	CARSAMMA	8
Panama	HP2110DAE	CARSAMMA	8

State of Operator/Registry	Aircraft Registration	RMA	Count of Observations
Panama	HP3010	CARSAMMA	1
United States	N101CT	NAARMO	3
United States	N15VC	NAARMO	2
United States	N16KB	NAARMO	5
United States	N228MD	NAARMO	7
United States	**N269RC**	**NAARMO**	**1**
United States	N2700	NAARMO	1
United States	**N31YA**	**NAARMO**	**4**
United States	N339AV	NAARMO	4
United States	**N375TC**	**NAARMO**	**33**
United States	N38EA	NAARMO	1
United States	**N397MG**	**NAARMO**	**4**
United States	**N43AG**	**NAARMO**	**4**
United States	N450BD	NAARMO	1
United States	N468HW	NAARMO	2
United States	N518RC	NAARMO	4
United States	N530RA	NAARMO	1
United States	N580BD	NAARMO	3
United States	N600EA	NAARMO	1
United States	N63FX	NAARMO	2
United States	N717LF	NAARMO	2
United States	N717MT	NAARMO	3
United States	N740TT	NAARMO	2
United States	**N800CJ**	**NAARMO**	**4**
United States	N834MM	NAARMO	11
United States	N902AU	NAARMO	2
United States	N960AA	NAARMO	1
United States	N973EM	NAARMO	23
United States	**N994EA**	**NAARMO**	**8**
Venezuela	YV2716	CARSAMMA	2
Venezuela	YV3052	CARSAMMA	2
Venezuela	YV3071	CARSAMMA	1

4. Reported Large Height Deviations (LHDs)

4.1 The NAARMO receives monthly LHD reports for Mexico and GOMEX airspace. There were fifty-six reported LHDs during calendar year 2019. This total includes five reported LHDs from Houston CTA/FIR. After scrutiny group review, twenty-eight of the fifty-six reported LHDs were determined to be risk-bearing. **Table 4-1** contains a summary of all the qualifying reported LHDs by month. The last row of

Table 4-1 shows there were 33.5 minutes of flying time at an unexpected/incorrect flight levels and sixteen flight levels crossed without clearance/incorrectly.

Table 4-1. Qualifying Reported LHDs for Mexico and GOMEX Airspace – 2019

Month	Count	Duration at Incorrect FL	Number of FLs Crossed
January 2019	0	0	0
February 2019	6	8.5	2
March 2019	3	2.5	0
April 2019	3	4.0	5
May 2019	3	12.5	0
June 2019	4	1.0	9
July 2019	2	0.5	0
August 2019	1	0	0
September 2019	0	0	0
October 2019	3	2.5	0
November 2019	2	1.0	0
December 2019	1	1.0	0
Total 2019	**28**	**33.5**	**16**

4.2 An LHD event with a duration of twenty minutes or more is considered to be a long duration event. There were zero reported long duration LHD events in 2019. In 2018, there were three long duration LHDs reported.

4.3 The scrutiny review determined the cause for each of the twenty-eight qualifying LHD reports in 2019. Twenty-one of the qualifying LHD reports involve coordination errors in the ATC transfer (LHD categories E and F). **Table 4-2** summarizes the qualifying LHD reports by cause.

Table 4-2. Qualifying LHD Reports by Cause – 2019

LHD Category Code	LHD Category Description	Number of LHD	Duration at Incorrect FL	Number of FLs Crossed
C	Incorrect operation or interpretation of airborne equipment	3	0	9
D	ATC Loop Error	1	0	2
E	Coordination errors in the ATC -to-ATC transfer of control responsibility as a result of human factors issues	19	27.5	0
F	Coordination errors in the ATC -to-ATC transfer of control responsibility as a result of an outage or technical issues	2	4	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight	1	0	5

LHD Category Code	LHD Category Description	Number of LHD	Duration at Incorrect FL	Number of FLs Crossed
	level (e.g. pressurization failure, engine failure)			
L	An aircraft being provided with RVSM separation is not RVSM approved	2	2	0
	TOTALS	**28**	**33.5**	**16**

4.4 **Figure 4-1** shows the approximate aircraft locations for the twenty-eight qualifying reported LHDs in 2019.

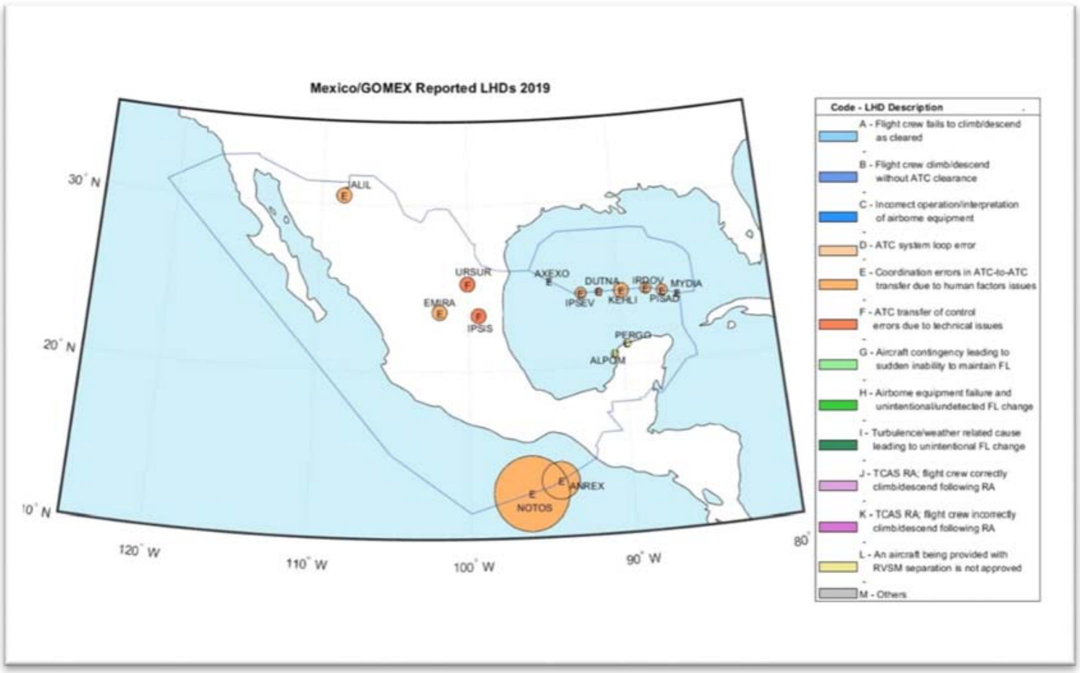

Figure 4-1. Qualifying LHD Reports – 2019

4.5 The reported LHDs are summarized by the traffic flows described in paragraph 2.4. The three traffic flows identified include GOMEX, offshore/oceanic, and Mexico domestic airspace.

4.6 GOMEX Airspace

4.6.1 The NAARMO organized scrutiny group teleconferences between Mexico ATC and Houston ATC to review the events reported during 2019. There were fifteen reported LHDs for the GOMEX traffic flow in 2019. Fourteen of the reported LHDs involved category E LHDs. The current Letter of Agreement (LOA) for the transfer of aircraft operations between Mexico and the United States requires verbal coordination in non-radar airspace. When automatic dependent surveillance – broadcast (ADS-B) data are available at both the U.S. and Mexico ATC facilities, the LOA might change to allow automated transfers. The U.S. ADS-B rule became effective in January 2020; Mexico indicated the ADS-B mandate is expected during the 2021 calendar year.

4.6.2 The fourteen category E reported LHDs in 2019 were an increase over the three category E reported LHDs in 2018 for GOMEX airspace. The reason for this increase was given as better reporting during 2019. A few occurrences in the early part of 2019 caused more reporting and changes to ATC training.

4.7 Offshore/Oceanic Airspace

4.7.1 There were three reported category E LHDs within the oceanic traffic flow in 2019. This was an increase over the one reported category E LHD in 2018. The errors in ATC transfer of control responsibility involve Mexico FIR and Central America FIR for the reported LHDs. The total duration associated with the 2019 reports is fifteen minutes, which is less than the twenty-six minutes reported in 2018.

4.8 Mexico Domestic Airspace

4.8.1 There were seven reported LHDs for Mexico airspace in 2019. Four of these reported LHDs involved errors in the ATC transfer of control responsibility between adjacent FIRs classified as category E and F. The total duration associated with the category E and F LHDs was eight minutes.

4.8.2 One the reported LHDs involve a contingency event (category G) with the pilot reporting pitot tube failure and descending through five flight levels without clearance. The two remaining LHDs involve auto pilot failure causing the aircraft operation to be no longer eligible for RVSM (category L), each of these reports have a duration of one minute.

4.9 **Figure 4-2** shows the observed trend in the number of reported LHDs related to ATC causes from 2017 through 2019. The data show an overall increase in the number of reported LHDs due to ATC causes. **Figure 4-3** shows the observed trend in the reported LHD durations related to ATC causes from 2017 through 2019. These data show a decrease in the reported LHD durations related to ATC causes.

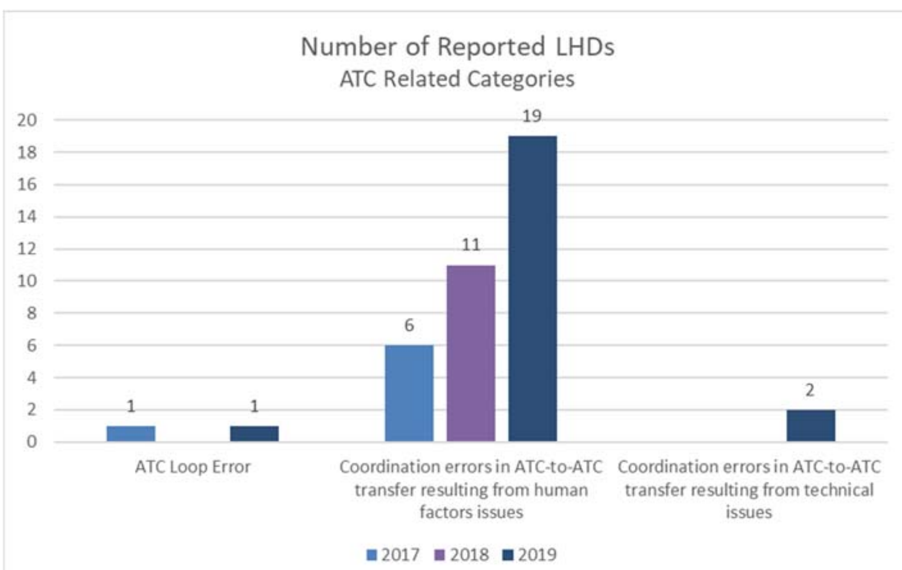

Figure 4-2. Observed Trend in Number of Reported LHDs – ATC Related Causes

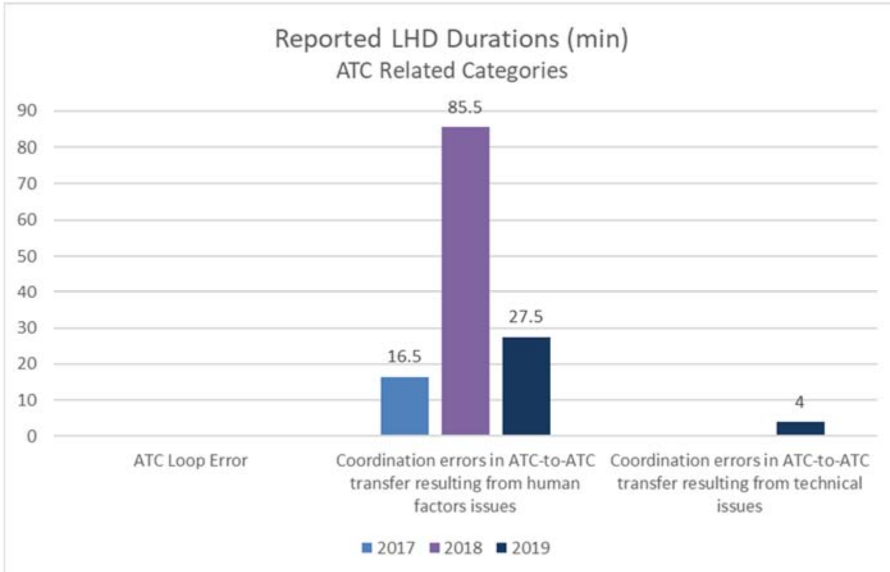

Figure 4-3. Observed Trend in Reported LHDs Durations – ATC Related Causes

4.10 Communication Failure Reports

4.10.1 There were twenty-eight reported occurrences specifying communication failures between ATC and the aircraft over a period of time. There were no indications of pilot deviation from either the cleared route or altitude during the period of communication failure. Because there were no indications of deviation from cleared route or altitude, there is no contribution towards the estimate of vertical collision risk.

4.10.2 The trend in the number of communication failure reports has decreased. During the previous calendar years 2018, 2017 and 2016, there were 58, 27 and 15 such reports, respectively.

4.10.3 In calendar year 2017, the twenty-seven communication failure reports accounted for 805 minutes in which ATC could not communicate with an aircraft. In calendar year 2018, the fifty-eight communication failure reports accounted for 1,587 minutes in which ATC was not able to communicate with an aircraft. In calendar year 2019, the twenty-eight communication failure reports accounted for 842 minutes in which ATC could not communicate with an aircraft.

4.10.4 The top two locations, in terms of the communication failure duration, are airspace fixes ELURA and DUPLO. The ELURA airspace fix was the top location in terms of duration in 2018 and 2017.

4.10.5 There were four reports of communication failure near the airspace fix ELURA, accounting for 173 minutes of ATC unable to communication with an aircraft. This represents a decrease in both the number of reports and associated duration. In 2018, there were fourteen reports of communication failure near ELURA accounting for 416 minutes of ATC unable to communicate with an aircraft. **Figure 4-4** provides the general location for all the reported communication failure reports. The size of the icon reflects the total duration of reported communication failures at the airspace fix location. The color of the circle in Figure 4-4 represents the total count of reports received for the location.

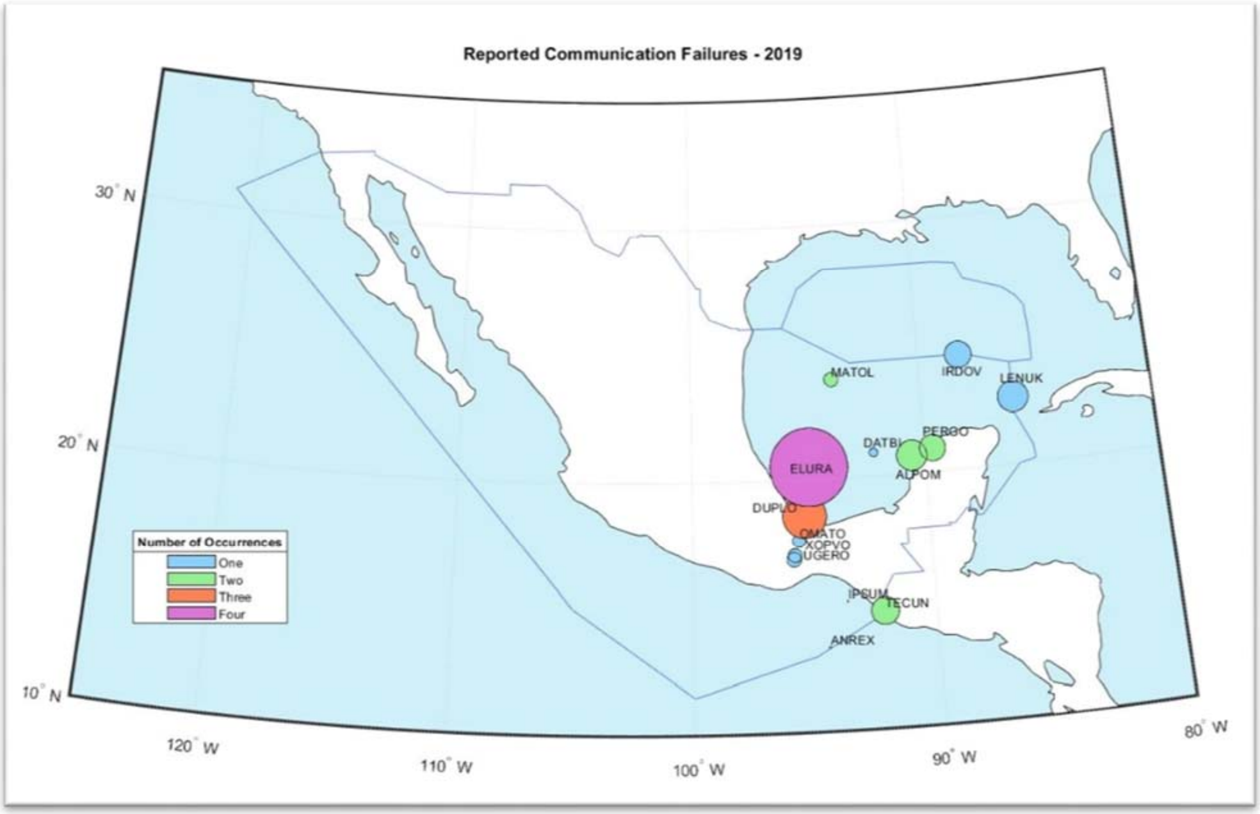

Figure 4-4. Reported Communication Failures - 2019

4.10.6 The aircraft operators involved in the communication failure reports are listed in **Table 4-3**. The top operator in terms of both number of reports and duration are International General Aviation (IGA) operators. Three of the IGA operators are U.S. aircraft registrations, one of the IGA operators is a Mexico aircraft registration.

4.10.7 This result is a change from that reported in 2018 where four commercial airlines were involved with 33 reported communication failures accounting for 889 minutes. It is possible that the coordination between Mexico and IATA has helped to improve these results. NAARMO helped to establish a relay of the communication failure reports from Mexico to IATA in order to solicit an operator response for the reported occurrences. Many airline operators clear the data from their systems within a month of the flight, having more timely reports provides them an opportunity to respond. This information help in determining the related cause(s).

Table 4-3. Operators involved in the communication failure reports – 2019

ICAO Operator Code	Operator Name	State of the Operator/ Registry	Number of Reports	Duration (minutes)
IGA	International General Aviation (IGA) Operators	Various	4	171
AMX	AEROVIAS DE MEXICO S.A. DE C.V.	MEXICO	3	120
VOI	VOLARIS	MEXICO	3	118
AIJ	ABC AEROLÍNEAS S.A. DE C.V.	MEXICO	3	80

ICAO Operator Code	Operator Name	State of the Operator/ Registry	Number of Reports	Duration (minutes)
VIV	AEROENLACES NACIONALES S.A. DE C.V.	MEXICO	2	78
GMT	GRUPOAEREO MONTERREY, S.A. DE C.V.	MEXICO	3	72
DAL	DELTA AIR LINES, INC.	USA	2	64
RPB	AEROREPUBLICA	COLUMBIA	1	32
TPU	TRANS AMERICAN AIRLINES S.A	PERU	1	31
AAL	AMERICAN AIRLINES INC	USA	1	29
CMP	COMPAÑÍA PANAMEÑA DE AVIACIÓN, S.A.	PANAMA	2	26
LET	AEROLINEAS EJECUTIVAS, S.A. DE C.V.	MEXICO	2	16
STATE	STATE AIRCRAFT OPERATIONS	Various	1	5

5. Vertical Collision Risk Estimation

5.1 This section of the paper provides the parameter estimates used in the ICAO vertical risk model. The collision risk methodology consists of a mathematical model to estimate risk for comparison to the safety criterion, the target level of safety (TLS). The section also provides information on the sources of data used to estimate risk model parameters.

5.2 The internationally agreed TLS for the 1 000-ft vertical separation standard is specified for technical and operational risk separately. The vertical technical risk provides the risk associated the effects of turbulence, loss of altitude hold and crew response to airborne collision-avoidance system alerts in addition to errors arising from aircraft altimetry and altitude height-keeping system performance. The vertical operational risk estimate provides the risk associated with operational errors. The risk due to all causes is the sum of the vertical operational and technical risk estimates. The TLS for the 1 000-ft vertical separation standard is specified as:

a) collision risk due to all causes does not exceed 5 fatal accidents in 10^9 flying hours, and, simultaneously,

b) collision risk due to aircraft height-keeping systems does not exceed 2.5 fatal accidents in 10^9 flying hours

5.3 Based on the December 2019 TFMS data, the NAARMO estimates approximately 1,206,229 annual flying hours for 2019 in Mexico and GOMEX airspace where the RVSM is applied. **Table 5-1** shows the flying hours within each identified traffic flow. Since a collision due to the loss of 1 000-ft vertical separation is assumed to result in two fatal accidents, the TLS can be expressed as 2.5 fatal midair collisions due to all causes in 10^9 flying hours.

5.4 Mexico and GOMEX airspace consists of a combination of parallel and crossing routes; therefore, the total risk is expressed as the sum of three basic types of collision risk as follows:

$$N_{az}=N_{az}(same)+N_{az}(opp)+N_{az}(cross) \quad (1)$$

The terms on the right hand side of the equation represent the expected number of accidents per aircraft flight hour resulting from collisions of aircraft-pairs on the same, opposite and crossing routes, respectively due to the loss of vertical separation between aircraft at adjacent flight levels.

Table 5-1. Flying Hours by Traffic Flow - 2019

Traffic Flow	2019 Flying hours	Proportion of Traffic
GOMEX	273,750	22.7%
Offshore/Oceanic	25,000	2.1%
Domestic	907,479	75.2%
Total	**1,206,229**	**100%**

5.5 The models for the three different types of collision risk - opposite-direction, same-direction, and crossing-routes - have basically the same structure. The estimate of vertical operational risk for same and opposite direction traffic is composed of two parts: that due to time spent at incorrect levels and that due to levels transitioned without clearance.

5.6 Aircraft Types Observed in Mexico & GOMEX Airspace

5.6.1 **Figure 5-1** provides the top 25 aircraft types observed in the December 2019 TFMS Mexico and GOMEX traffic data by flying hours. These aircraft types account for 95 percent of total flying hours observed in Mexico and GOMEX airspace. The percentage of flying hours observed for the Boeing 737 NGX family; including B737, B738, and B739, is 55 percent of all the flying hours observed in the traffic data. The percentage of flying hours observed for the Airbus A320 family; including the A319, A320, and A321, account for 20 percent of all the flying hours observed in the traffic data.

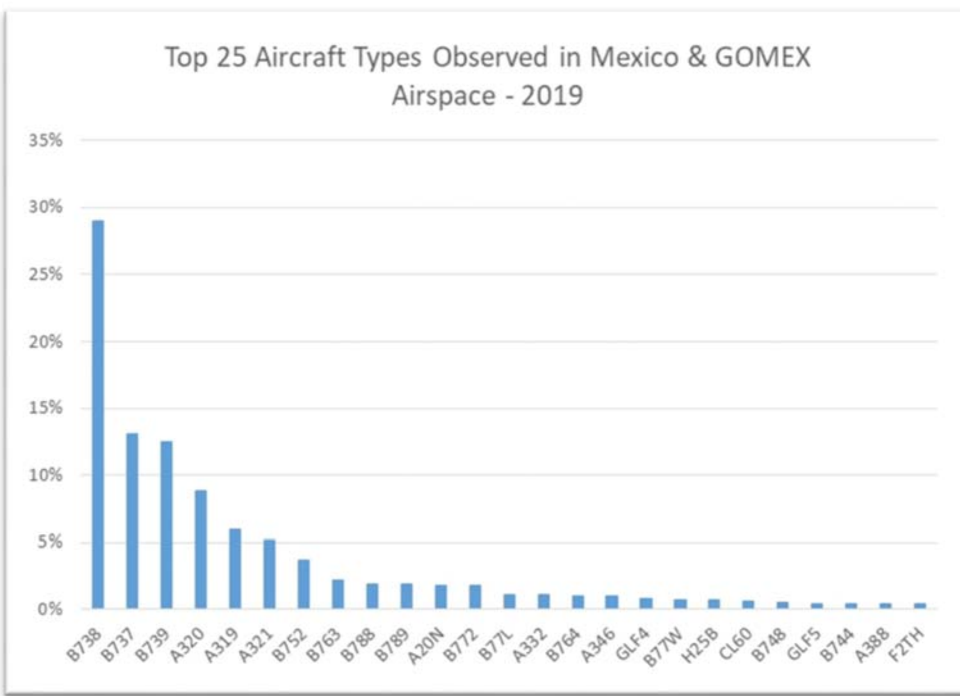

Figure 5-1. Observed Aircraft Types in Terms of Flying Hours in Mexico & GOMEX Airspace (2019)

5.7 *Aircraft Size*

5.7.1 The collision risk model parameters related to the aircraft size are: length, wingspan, and height. These parameters are estimated directly from the December 2019 TFMS data and related aircraft specifications. The weighted dimensions are calculated using the actual dimensions of the aircraft type multiplied by the proportion of total flying time observed for the type in the traffic sample. The resulting CRM parameters for the aircraft length, wingspan, and height are presented in **Table 5-2**.

Table 5-2. CRM Parameter Estimates for Aircraft Size

Length λ_x (NM)	Wingspan λ_y (NM)	Height λ_z (NM)
0.0224	0.0201	0.007

5.8 Same-Direction, Opposite-Direction, and Crossing-Route Vertical Passing Frequencies

5.8.1 The TFMS data is used to estimate the number of vertical aircraft passings per hour for each of the three traffic flows; GOMEX, offshore/oceanic, and domestic. The reason for separating the traffic into three separate flows is to account for areas of low and high traffic densities. **Table 5-3** provides the same and opposite direction vertical occupancies by traffic flow. The traffic flow with the lowest traffic density is the offshore/oceanic traffic flow, followed by the GOMEX airspace. As expected, the Mexico domestic airspace has the highest vertical occupancy values compared to the other two traffic flows.

Table 5-3. Vertical Occupancies by Traffic Flow

Traffic Flow	Same Direction Vertical Occupancy	Opposite Direction Vertical Occupancy
GOMEX	0.070	0.137
Offshore/Oceanic	0.000	0.006
Domestic	0.334	0.064

5.8.2 Crossing route vertical occupancy is estimated by the number of vertically proximate aircraft pairs on routes that cross at a specific angle, ϑ. Both mathematical considerations and experience in previous safety assessments have established that the vertical occupancy estimated for pairs of aircraft at intersections of routes is generally less by an order of magnitude than that for pairs of aircraft on the same route at adjacent flight levels. Thus it is expected that the collision risk estimate for crossing routes will be below the risk for same route adjacent flight levels. The number of crossing-route aircraft pairs for the calendar year 2019 is 190,262 aircraft pairs.

5.9 Probability of Vertical Overlap Attributable to Technical Height-Keeping Performance and Reported LHDs

5.9.1 RVSM technical risk is considered to arise from the effects of turbulence, loss of altitude hold and crew response to airborne collision avoidance system alerts as well as from errors in aircraft altimetry and altitude-keeping system performance. Hence, estimation of the probability of vertical overlap must account for contributions to vertical error arising from all of these sources.

5.9.2 Estimates of aircraft altimetry system error (ASE) are obtained from aircraft height monitoring processes developed by NAARMO. These processes require several data sets, including meteorological and aircraft geometric height data. Aircraft geometric data is obtained from either the U.S. Aircraft Geometric Height Monitoring Element (AGHME), Automatic Dependent Surveillance – Broadcast (ADS-B) data, or the GPS Monitoring Unit (GMU) system. Control of aircraft ASE is one of the principal objectives of the State RVSM approval process, which must be held by operators in airspace where the RVSM is applied.

5.9.3 The NAARMO estimate for the probability of vertical overlap for aircraft pairs operating on adjacent flight levels, $P_z(1\ 000)$, used in the estimate of vertical technical risk is 1.93×10^{-9}. The NAARMO estimate for the probability of vertical overlap for aircraft pairs operating on the same flight level, $P_z(0)$,used in the estimation of vertical operational risk is 0.42.

5.10 Time spent at Unexpected FL

5.10.1 The proportion of flying time spent at incorrect levels, P_i, is determined as the ratio of the amount of time spent at incorrect levels to the total amount of flying time in the Mexico airspace during the period when the wrong-flight-level events occurred. The qualifying LHDs for calendar year 2019 contain 33.5 minutes of flying time spend at unexpected flight level. This time is split into the three identified traffic flows based on the location provided in the reported LHD. **Table 5-4** provides the breakdown of reported LHD duration and flight levels crossed by identified traffic flow.

Table 5-4. Reported LHD Duration and Flight Levels Crossed by Traffic Flow

Traffic Flow	Reported LHD duration (min)	Number of flight levels crossed without clearance
GOMEX	8.5	2
Offshore/Oceanic	15	0
Domestic	10	14
TOTAL	**33.5**	**16**

5.11 Collision Risk Model Parameters

5.11.1 The individual parameters of the models, their definitions, estimates, and sources are given in **Table 5-5**. These parameters are common to the vertical risk estimate for all identified traffic flows.

Table 5-5. Vertical Collision Risk Model Parameter Estimates

Term	Definition	Estimate	Source
$P_z(S_z)$	Probability that two aircraft operating on the same route nominally separated by the vertical separation minimum S_z are in vertical overlap.	1.93×10^{-9}	Value used in the US CONUS vertical risk estimate
$P_z(0)$	Probability that two aircraft operating on the same route and flight level are in vertical overlap.	0.42	Value used in the US CONUS vertical risk estimate
$P_y(0)$	Probability that two aircraft on the same track are in lateral overlap.	0.1	Value used in the vertical risk estimates for Pacific airspace
λ_x	Average aircraft length.	0.0224 NM	Estimated using December 2019 Mexico TFMS sample
λ_y	Average aircraft wingspan.	0.0201 NM	Estimated using December 2019 Mexico TFMS sample
λ_z	Average aircraft height with undercarriage retracted.	0.0064 NM	Estimated using December 2019 Mexico TFMS sample
$\overline{\lvert \Delta V \rvert}$	Average absolute relative along-track speed between aircraft on same-direction routes.	13 knots	Value used in the North Atlantic, Pacific, and US Domestic airspace vertical risk estimates
$\overline{\lvert V \rvert}$	Average absolute aircraft ground speed.	480 knots	Value used in the North Atlantic, Pacific, and US Domestic airspace vertical risk estimates
$\overline{\lvert \dot{y} \rvert}$	Average absolute relative cross-track speed for an aircraft pair nominally on the same route.	5 knots	Value used in the North Atlantic, Pacific, and US Domestic airspace vertical risk estimates
$\overline{\lvert \dot{z} \rvert}$	Average absolute relative vertical speed of an aircraft pair that have lost all vertical separation	1.5 knots	Value used in the North Atlantic, Pacific, and US Domestic airspace vertical risk estimates

6. Results and Conclusions

6.1 **Table 6-1** provides 2019 estimates of technical and operational vertical risk for Mexico and GOMEX airspace.

Table 6-1. 2019 Vertical Risk Estimates for Mexico and GOMEX RVSM Airspace

Description	Risk Estimate ($\times 10^{-9}$ fapfh)
Estimate of Technical Risk	**0.07**
Estimate of Risk Due to Operation at Incorrect Flight Levels	**4.85**
Estimate of Overall Risk	**4.92**

6.2 The estimated technical risk in the Mexico and GOMEX RVSM airspace is 0.07×10^{-9} fatal accidents per flight hour (fapfh). This estimate is significantly below 2.5×10^{-9} fapfh, which is the portion of the TLS set as the safety goal for technical height-keeping performance.

6.3 The operational risk estimate for Mexico and GOMEX RVSM airspace 4.85×10^{-9} fapfh. The sum of this value and the technical risk estimate for Mexico airspace is 4.92×10^{-9} fapfh, which is below the overall safety goal of 5.0×10^{-9} fapfh.

6.4 **Table 6-2** provides the overall vertical risk estimates for calendar years 2015 – 2019 for Mexico RVSM airspace. The increase in the vertical risk estimate for calendar year 2018 occurred because of three long duration reported LHDs. In 2019, the calculation method was slightly different compared to the previous estimates. In 2019, three traffic flows were identified and used to estimate associated parameters in the risk model. For example, the risk calculated for a reported LHD that occurred in a low traffic density, non-radar section of airspace will have a smaller risk value compared to an LHD within a high traffic density area.

Table 6-2. Overall Vertical Risk Estimates for Mexico RVSM Airspace

Calendar Year	Vertical Collision Risk Estimate ($\times 10^{-9}$ fapfh)
2015	4.8
2016	4.8
2017	3.2
2018	16.7
2019	**4.92**

— END —