International Civil Aviation Organization
North American, Central American and Caribbean Office

INFORMATION PAPER

GTE/20 — IP/04
03/11/20

CAR/SAM Planning and Implementation Regional Group (GREPECAS) Twentieth Scrutiny Working Group Meeting (GTE/20)

Online, 9 – 11 November 2020

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

MIAMI OCEANIC, NEW YORK WEST, AND SAN JUAN 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 Miami Oceanic, New York West, and San Juan 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) 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 Miami Oceanic, New York West, and San Juan Airspace. This report contains a summary of LHD reports received by the NAARMO for the calendar year 2019. There are 26 reported events accounting for 45.5 minutes spent at an unexpected/incorrect flight level (FL) during calendar year 2019. This report also contains an estimate of the vertical collision risk. The vertical collision risk estimate for the airspace exceeds 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 • 2019 Traffic Sample Data (TSD) from FAA Advanced Technologies and Oceanic Procedures (ATOP) oceanic automation system data reduction and archives (DR&A) • FAA Traffic Flow Management System (TFMS) • ICAO Doc 9574 • ICAO Doc 9937

1. Introduction

1.1. 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 the Miami Oceanic, New York West, and San Juan airspace.

1.2. This airspace primarily contains operations travelling between North America and the Caribbean. The U.S. FAA is the ATS provider for the Miami Oceanic, New York and San Juan Flight Information Regions (FIRs). **Figure 1-1** shows the location of the airspace. The RVSM was introduced in November 2001 into this airspace. The NAARMO conducts the on-going airspace safety monitoring activities to help ensure the continued safe use of the RVSM.

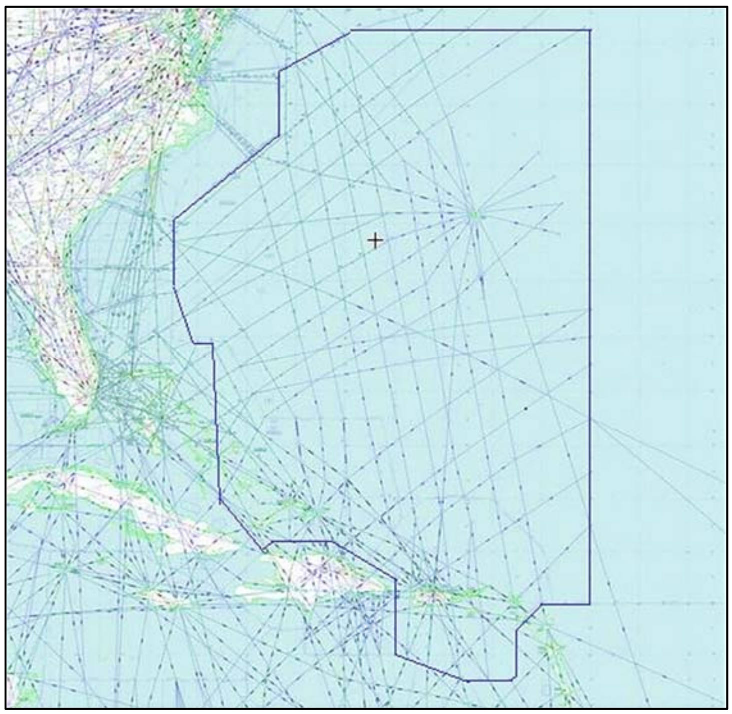

Figure 1-1. Miami Oceanic, New York West, San Juan FIRs

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. There were 26 such reports submitted to the NAARMO for calendar year 2019.

2. Traffic Sample Data

2.1 The NAARMO has access to the Federal Aviation Administration's (FAA's) Traffic Flow Management System (TFMS), which includes aircraft observations in Miami Oceanic and San Juan airspace. Each traffic movement record within the TFMS data sample contains the date, time, latitude, longitude, flight level (FL), 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.

2.2 The source of traffic data for the New York West FIR is the FAA Advanced Technologies and Oceanic Procedures (ATOP) oceanic automation system data reduction and archives (DR&A). These data contain all the reported aircraft positions, as well as the pilot-ATC high frequency (HF) radio communications and controller pilot data link communications (CPDLC) messages. Figure 2-1 shows the aircraft position locations within the New York West FIR and the TFMS data for the Miami Oceanic and San Juan FIRs for 10 December 2019. The Miami Oceanic and San Juan traffic observed in the TFMS data are combined with the New York West traffic observed in the ATOP DR&A.

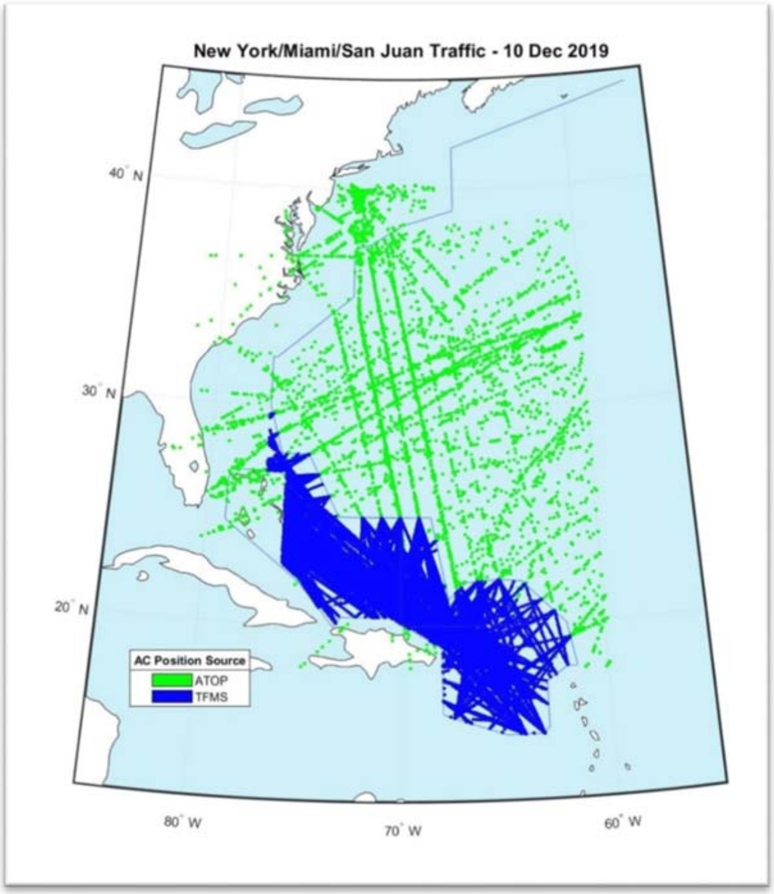

Figure 2-1. Miami Oceanic, San Juan, and New York West FIRs – 10 December 2019

2.3 **Figure 2-2** shows the number of flights by day in the New York West FIR for December 2019. The vertical bars represent the number of flight operations each day observed in the data sample. The average number of flight operations per day observed in the data is 652 flights per day in December 2019. This represents a slight increase in the number of flight operations per day; in December 2018 this analysis showed 593 flight operations per day.

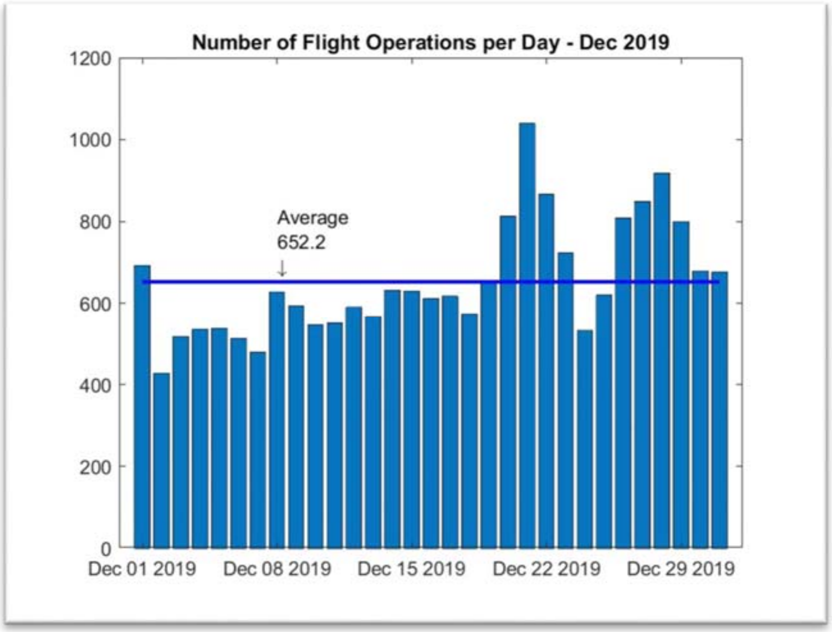

Figure 2-2. Number of Flight Operations Observed by Day – New York West FIR December 2019

3. Reported Large Height Deviations (LHDs)

3.1 The NAARMO utilizes the FAA's Comprehensive Electronic Data Analysis and Reporting (CEDAR) database, which contains all reports of potentially safety-related events from several internal FAA sources. There were twenty-six reported events during calendar year 2019 reviewed by the scrutiny group for the Miami Oceanic, New York West, and San Juan airspace. The scrutiny group consists of operational experts from each air traffic control facility and safety analyses experts from the NAARMO. **Table 3-1** contains a summary of all the risk-bearing LHDs by month.

Table 3-1. Risk-bearing LHDs – 2019

Month	Count	Duration at Unexpected FL (mins)	Number of Unexpected FLs Crossed
Jan-19	2	16	1
Feb-19	6	12.5	5
Mar-19	2	1.5	0
Apr-19	1	0	0
May-19	1	0	1
Jun-19	1	0.5	0
Jul-19	2	0	0
Aug-19	3	9	0
Sep-19	0	0	0
Oct-19	3	3.5	3
Nov-19	4	2	2
Dec-19	1	0.5	0
TOTAL	**26**	**45.5**	**12**

3.2 The scrutiny review determined a general cause for each of the twenty-five risk-bearing LHD reports in 2019. **Table 3-2** summarizes the risk-bearing reported LHDs categorized by general cause. Reported category A LHDs had the largest contribution to duration at incorrect flight levels (FL) in 2019.

Table 3-2. Risk-bearing LHD Reports by Cause – 2019

LHD Category Code	LHD Category Description	Number of LHD	Duration at Incorrect FL (minutes)	Number of Incorrect FLs Crossed
A	Flight crew failing to climb / descend the aircraft as cleared	6	18	6
B	Flight crew climbing /descending without ATC clearance	3	0	1
C	Incorrect operation of airborne equipment	0	0	0
D	ATC system loop error; (e.g., ATC issues incorrect clearance or flight crew misunderstands clearance message)	5	11.5	2
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility as a result of human factors issues	6	2	3
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues	3	5	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level	0	0	0
H	Airborne equipment failure leading to unintentional or undetected change of flight level	0	0	0
I	Turbulence or other weather related causes	1	0	0
M	Other – correct application of Wx contingency procedure, use different vertical overlap probability	2	9	0
	TOTAL	**26**	**45.5**	**12**

3.3 A decrease in the duration spent at the unexpected/incorrect flight level (FL) associated with reported LHDs is observed in 2019 compared to the previous two years. There are 105 minutes in year 2018 and 202 minutes in year 2017.

3.4 **Figure 3-1** shows the comparison in number of risk-bearing LHD reports observed in 2019 with previous years results by LHD category. The vertical axis shows the observed counts within each LHD category. The categories in which the number of risk-bearing reports had observed increases in 2019 were in the pilot failure to climb/descend as cleared (category A), and ATC loop error (category D). The two reported LHDs classified as category M, Other, involve the correct application of weather deviation procedures. In these cases, the additional risk is measured for two aircraft having +/- 300-ft vertical separation during the weather deviation occurrence.

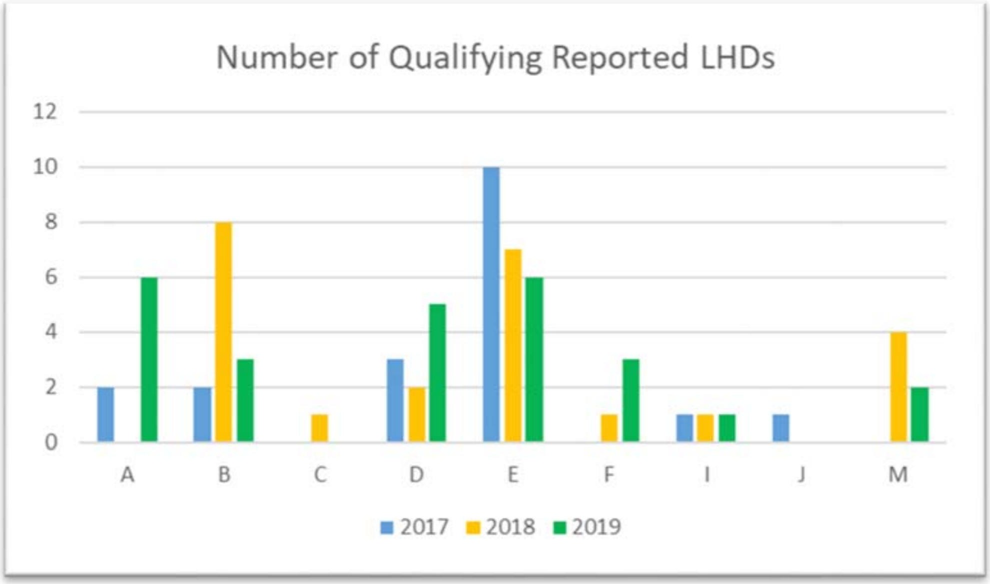

Figure 3-1. Number of reported risk-bearing LHDs by category code, 2017 - 2019

3.5 **Figure 3-2** shows the comparison of the associated duration for reported LHDs in 2019 with the previous years results by LHD category. The vertical axis shows the sum of the reported durations within each LHD category. There was more time associated with reported LHDs involving air crew failing to climb/descend as cleared (category A) in 2019 compared to 2018. The remaining LHD categories show less duration at incorrect FL in 2019 compared to previous years.

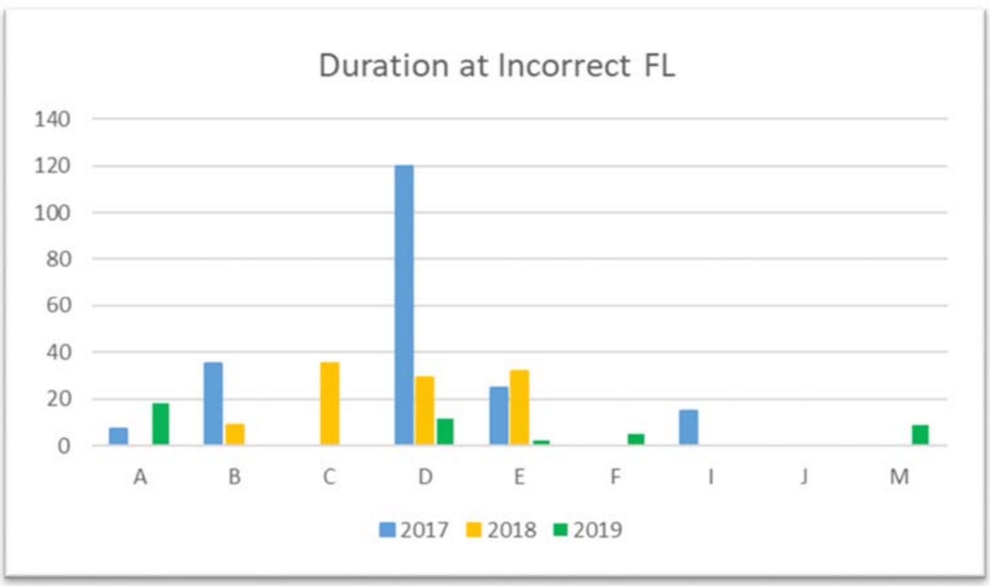

Figure 3-2. Duration at incorrect FL (minutes) by LHD category, 2017 - 2019

3.6 The definition of a long duration LHD is one with a duration of twenty or more minutes. There were zero long duration LHDs reported in 2019. For comparison, there was one long-duration LHD reported in 2018.

3.7 The reported LHD with category code 'I' involved turbulence. This reported LHD is attributed towards technical risk not operational risk. The pilot reported 500 ft vertical deviation due to severe turbulence. There was no reported loss of separation for this occurrence.

3.8 Two of the three category F reported LHDs were caused by errors in automated coordination. In these cases, the aircraft traveled from oceanic airspace into radar coverage airspace, and then returned to oceanic airspace. The re-entry into oceanic airspace was not coordinated properly in these occurrences. The total time spent at unprotected flight levels was five minutes. The last occurrence of this problem was in November 2019. The fix for this problem was implemented in the ATOP software, there have been no repeat occurrences reported to date.

3.9 There were four reported category A LHDs that were caused by misunderstanding of CPDLC conditional clearances. The total time spent at incorrect flight level was seventeen minutes. One reported occurrence accounted for sixteen of the seventeen minutes duration. All four of these occurrences involved the misinterpretation of an altitude change clearance delivered by ATC. The following CPDLC message sets are sometimes misunderstood:

3.9.1 UM21 - AT (time) CLIMB TO AND MAINTAIN (altitude)
3.9.2 UM24 - AT (time) DESCEND TO AND MAINTAIN (altitude)
3.9.3 UM26 - CLIMB TO REACH (altitude) BY (time)
3.9.4 UM28 - DESCEND TO REACH (altitude) BY (time)

3.10 The North Atlantic (NAT) region has studied reported occurrences involving conditional clearances. The use of AT or BY can be confusing to flight crews. The current version of the *NAT OPS Bulletin, OESB – Oceanic Errors,* is provided in Appendix A of this report. The Large Height Deviation section that begins on the third page of the bulletin contains definitions and practical information for aircraft operators receiving conditional clearances from ATC. Definitions for AT and BY in the context of altitude change clearances are given below:

3.10.1 "BY" means

- "Before passing" when referring to a **position**, or
- "Not later than" when referring to a **time**.

3.10.2 "AT" means

- "After passing" when referring to a **position**, or
- "Not before" when referring to a **time**.

3.11 The two reported category M LHDs involve the correct application of weather/contingency procedures that incur a measureable vertical due to the required 300 ft or 500 ft level change. The calculation of operational vertical risk for these occurrences involves the use of a different vertical overlap probability parameter, $P_z(300)$ or $P_z(500)$, instead of the usual $P_z(0)$. The probability of vertical overlap will be explained in latter sections of this report. There was a total of nine minutes spent where two aircraft were potentially separated by 300-ft for these reported occurrences.

3.12 The operational risk-bearing LHD events are separated into two areas; those occurring within New York West airspace and those occurring within the Miami Oceanic/San Juan Flight Information Regions (FIRs) and New York West boundary. **Table 3-3** contains the breakdown of risk-bearing LHD events and associated durations for each area. There are two rows for the New York West FIR in this table. The LHD duration associated with aircraft operating with potentially zero vertical separation ($P_z(0)$), and the LHD duration associated with aircraft operating with a nominal 300-ft vertical separation ($P_z(300)$). The latter classification is added to measure the additional risk associated with the correct application of the weather deviation procedure.

3.13 **Figure 3-3** shows the approximate locations of the risk-bearing LHDs in 2019. All of category E and F events occur on an ATC boundary. There is no apparent pattern or obvious trend in the location of the reported LHD events.

Table 3-3. Operational Risk-bearing Reported LHDs by Area – 2019

Airspace	Number of LHD	Duration at unexpected FL (min)	Number of unexpected FLs crossed
Miami Oceanic/San Juan FIRs and New York West boundary	7	12	1
New York West FIR *(Pz(0))*	18	24.5	11
New York West FIR *(Pz(300))*	1	9	0
Total	**25**	**45.5**	**12**

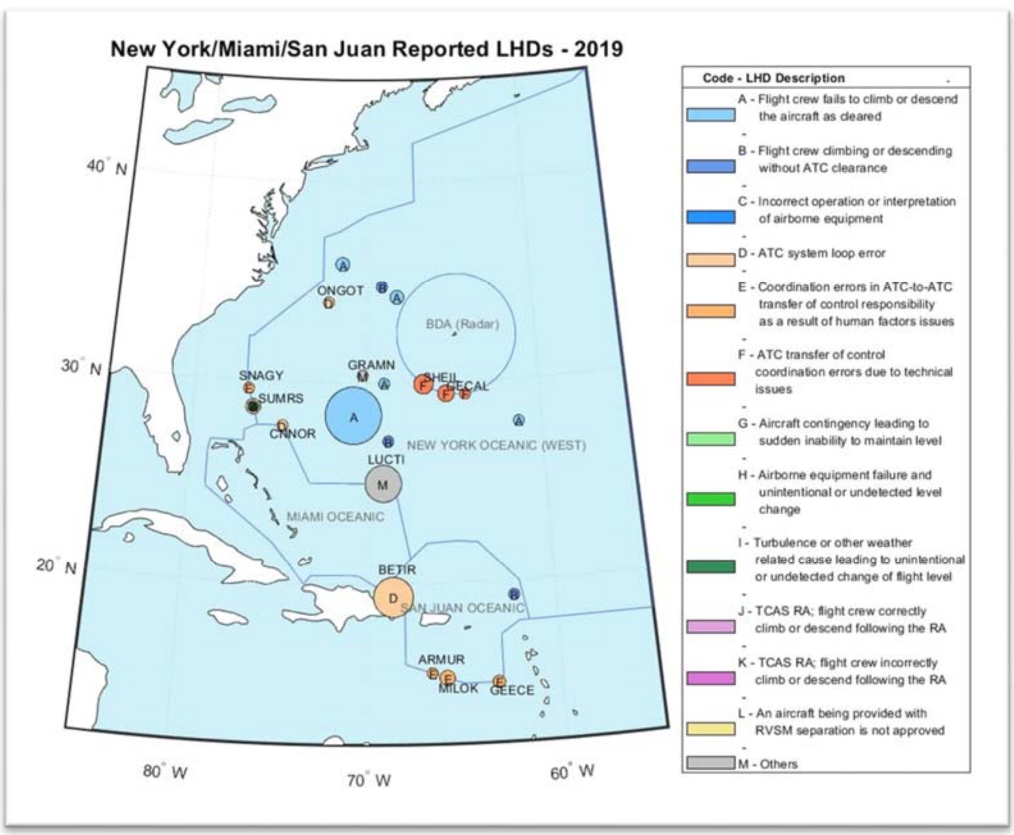

Figure 3-3. Approximate Location of the Risk-bearing LHDs – 2019

4. Vertical Collision Risk Estimation

4.1 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.

4.2 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 with 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

4.3 Based on the December 2019 traffic data, the NAARMO estimates approximately 519,324 annual flying hours for 2019 in Miami Oceanic, New York West, and San Juan airspace where the RVSM is applied.

4.4 The methodology applied in the collision risk calculation for the airspace splits the airspace into two areas. The New York West airspace is considered separately from Miami Oceanic and San Juan airspace. Although the aircraft operations are similar within both areas, the available ATC surveillance and communications differ. In addition, there are differences in the available traffic data source for the two areas. The individual risk estimates for each area are combined to provide an estimate of the airspace using the observed annual flying hours within each area.

4.5 The 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:

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

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 assigned to adjacent flight levels on routes where aircraft operating on adjacent flight levels are flying in the same direction on the same route, opposite direction on the same route and on crossing routes regardless of relative headings, respectively, due to the loss of planned vertical separation.

4.6 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.

4.7 *Aircraft Types Observed in Miami Oceanic, New York West, and San Juan FIRs*

4.7.1 **Figure 4-1** provides the top 15 aircraft types observed in the December 2019 traffic data by flying hours. The two traffic data sources are maintained in the figure; Miami Oceanic and San Juan traffic data are sourced from the TFMS and the New York West data are sourced from the ATOP DR&A. The aircraft types in **Figure 4-1** account for more than 70 percent of total flying hours observed in the airspace. The percentage of flying hours observed for the Boeing 737 NGX family; including the B737, B738 and B739 is 21 percent of all flying hours observed in the traffic data. The Airbus A320 is the second most frequently observed aircraft in the airspace. The percentage of flying hours observed for the Airbus 320 family; including A319, A320, and A321, is more than 20 percent of all the flying hours observed in the traffic data.

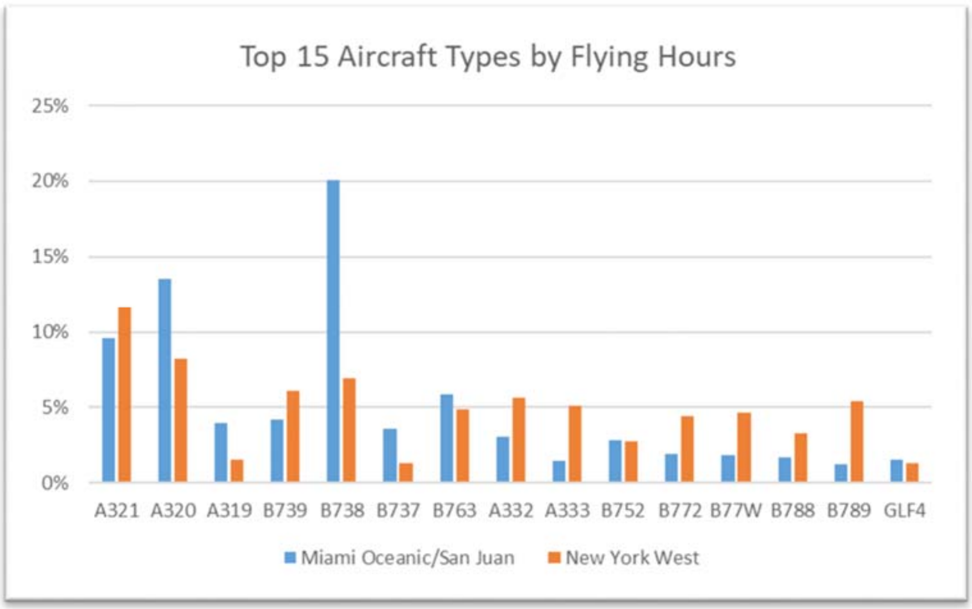

Figure 4-1. Observed Aircraft Types in Terms of Flying Hours in Miami Oceanic/San Juan and New York West Airspace

4.8 *Aircraft Size*

4.8.1 The collision risk model (CRM) parameters related to the aircraft size are: length, wingspan, and height. These parameters are estimated directly from the TFMS and ATOP DR&A December 2019 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 4-1**.

Table 4-1. CRM Parameter Estimates for Aircraft Size

Airspace	Length λ_x (NM)	Wingspan λ_y (NM)	Height λ_z (NM)
Miami Oceanic/San Juan	0.0230 *(140 ft)*	0.0206 *(125 ft)*	0.0069 *(42 ft)*
New York West	0.0271 *(165 ft)*	0.0247 *(150 ft)*	0.0077 *(47 ft)*

4.9 *Same-Direction, Opposite-Direction, and Crossing-Route Vertical Passing Frequencies*

4.9.1 The traffic data are used to estimate the vertical occupancy values for the airspace. Table 4-2 shows the same and opposite direction vertical occupancy estimates for the Miami Oceanic/San Juan and New York West airspace. The same direction vertical occupancy value for New York West airspace for 2019 is slightly lower than the value estimated in 2018. The opposite direction vertical occupancy value for New York West airspace for 2019 is 13 percent higher than the value estimated in 2018.

Table 4-2. Same and Opposite direction vertical occupancy estimates

Airspace	Same Direction Vertical Occupancy Value	Opposite Direction Vertical Occupancy Value
Miami Oceanic and San Juan	0.0372	0.0912
New York West	0.0345	0.0970

4.9.2 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 operations at adjacent flight levels. The number of crossing-route aircraft pairs observed in the December 2019 traffic sample from Miami Oceanic and San Juan airspace was 5,734. This value, prorated from the 31-sample days for the calendar year 2019, is 67,513 aircraft pairs annually.

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

4.10.1 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.

4.10.2 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.

4.10.3 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.

4.10.4 The probability of vertical overlap for aircraft pairs nominally separated by 300-ft, $P_z(300)$, is used in the estimate of operational vertical risk for specific reported occurrences. The weather deviation procedure for oceanic airspace was recently revised in conjunction with the implementation of reduced lateral separation minimum. The 2019 reported LHDs were reviewed and the time spent at +/- 300-ft from a cleared flight level was determined when the correct application of weather deviation procedure was used by the air crew. This duration is separated from the duration associated with other reported occurrences to account for the difference in expected vertical overlap probability.

4.11 *Time spent at Unexpected FL*

4.11.1 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 airspace during the period when the wrong-flight-level events occurred. The risk-bearing LHDs for calendar year 2019 contain 45.5 minutes of flying time spent at unexpected flight level.

4.11.2 **Table 3-3** (from page 8 of this document) provides the duration at unexpected/incorrect flight level for both areas. The proportion of flying time spent at unexpected flight level is estimated for each area using the values in the table and dividing by the estimated flying hours for each area. The estimated annual flying hours for New York West airspace obtained from the ATOP DR&A data are 277,504 hours. The estimated annual flying hours for Miami Oceanic and San Juan airspace obtained from the combined TFMS data are 313,820 flying hours. The ratios of time spent at unexpected flight level are 2.01×10^{-6} and 6.37×10^{-7} for New York West and Miami Oceanic/San Juan airspace, respectively.

4.12 *Collision Risk Model Parameters*

4.12.1 The individual parameters of the models, their definitions, estimates, and sources are given in **Table 4-3**.

Table 4-3. Vertical Collision Risk Model Parameter Estimates

Term	Definition	Estimate	Source
$P_z(S_z)$	Probability that two aircraft 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 flight level are in vertical overlap	0.42	Value used in the vertical risk estimates for Pacific airspace
$P_z(300)$	Probability that two aircraft which are nominally separated by 300-ft are in vertical overlap	0.01082	Value determine through ICAO Separation and Airspace Safety Panel (SASP)
$P_y(0)$	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.	0.0230 NM and 0.0271 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_y	Average aircraft wingspan.	0.0206 NM and 0.0247 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_z	Average aircraft height with undercarriage retracted.	0.0069 NM and 0.0077 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
$E_Z(same)$	Same-direction vertical occupancy for a pair of aircraft at adjacent flight levels on same route.	0.037 and 0.035	Estimated from Miami Oceanic/San Juan and New York West traffic data
$E_Z(opp)$	Opposite-direction vertical occupancy for a pair of aircraft at adjacent flight levels on same route.	0.091 and 0.097	Estimated from Miami Oceanic/San Juan and New York West traffic data
$\overline{\lvert\Delta V\rvert}$	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
$F(NY)$	Estimated flying hours within New York West FIR	277,504	Estimated from FAA ATOP DR&A for New York West airspace
$F(MS)$	Estimated flying hours within Miami Oceanic and San Juan FIRs	313,820	Estimated from TFMS data for Miami Oceanic and San Juan airspace

5 Results and Conclusions

5.1 The risk-bearing LHDs are separated based on the location of the event. The risk-bearing LHDs within New York West airspace are applied to the estimated flying hours and vertical occupancy values for New York West airspace. The same method is applied to the data for Miami Oceanic and San Juan airspace. **Table 5-1** provides the weighted 2019 estimates of technical and operational vertical risk for Miami Oceanic, New York West and San Juan airspace. The last row in **Table 5-1** contains the weighted sum of the risk from the two areas.

Table 5-1. 2019 Vertical Risk Estimates for Miami Oceanic, New York West and San Juan Airspace ($\times 10^{-9}$ fatal accidents per flight hour (fapfh))

Airspace	Technical	Operational	Overall
New York West	0.04	15.11	15.15
Same Flight Level, $P_z(0)$		*13.24*	
Nominal 300-ft vertical separation $P_z(300)$		*1.87*	
Miami Oceanic and San Juan	0.04	5.56	5.60
Total	**0.08**	**20.67**	**20.75**

5.2 The estimated technical risk in the RVSM airspace is 0.08 × 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.

5.3 The operational vertical risk estimate for RVSM airspace 20.67 × 10-9 fapfh. The sum of this value and the technical risk estimate for airspace is 20.75 × 10-9 fapfh, or four times greater than the overall safety goal of 5.0 × 10-9 fapfh. The category A reported LHDs contribute fifty-eight percent of the overall estimated vertical collision risk, or 12.1 × 10-9 fapfh.

5.4 The contribution to the vertical operational risk estimate from the correct application of the weather deviation procedure is provided in Table 5-1. There were two reported LHDs related to the correct application of the weather deviation procedure with nine minutes duration in 2019. The additional vertical risk associated with this procedure is calculated as 1.87 × 10-9 fapfh.

5.5 The estimated vertical risk estimate for 2019, shown in Table 5-1, is lower than the estimates for 2018, 2017 and 2016. The overall vertical risk estimates in 2018, 2017 and 2016 were 48.1, 87.5 and 219.2 x 10-9 fapfh, respectively. The decrease in the vertical risk estimate is attributed to less time spent at unexpected flight levels. The use of bi-directional routes leads to a high value of opposite-direction vertical occupancy. The vertical collision risk estimate is very sensitive to a high value of opposite-direction vertical occupancy.

— END —