International Civil Aviation Organization
South American Office

INFORMATION PAPER

GTE/19 — IP/14
06/11/19

CAR/SAM Planning and Implementation Regional Group (GREPECAS) Nineteenth Scrutiny Working Group Meeting
(GTE/19)
Barranquilla, Colombia, 18 to 22 November 2019

Agenda Item 3: **Review of the results of Large Height Deviation (LHD) analysis**

MIAMI OCEANIC, NEW YORK WEST, AND SAN JUAN AIRSPACE VERTICAL SAFETY MONITORING REPORT - 2018

(Presented by United States)

EXECUTIVE SUMMARY

This 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 2018.

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 2018. There are 24 reported events accounting for minutes spent at an unexpected/incorrect flight level during calendar year 2018. 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 2018 • 2018 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.

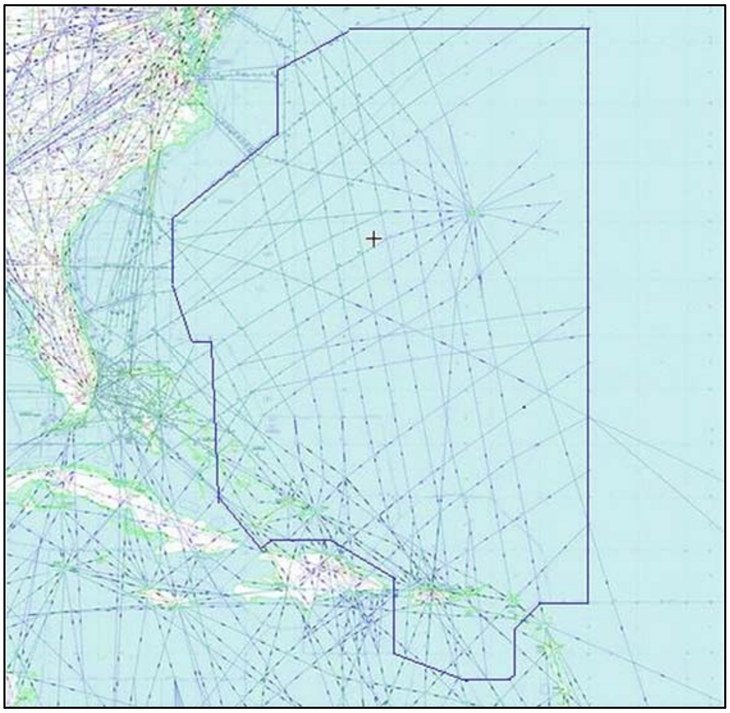

Figure 1-1. Miami Oceanic, New York West, San Juan FIRs

1.3 This report covers the calendar year 2018. 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 24 such reports submitted to the NAARMO for calendar year 2018.

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, 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 during December 2018. 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.

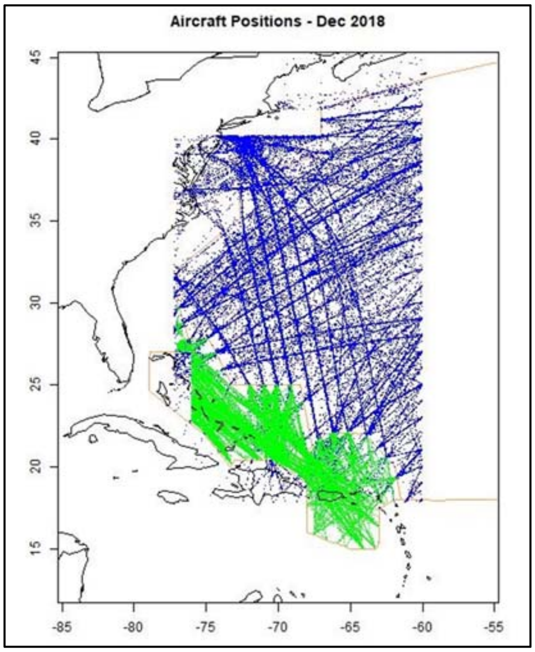

Figure 2-1. Miami Oceanic, San Juan, and New York West FIRs – December 2018

2.3 **Figure 2-2** shows the number of flights by day in the New York West FIR for December 2018. 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 593 flights per day in December 2018. This represents a slight increase in the number of flight operations per day; in December 2017 this analysis showed 553 flight operations per day.

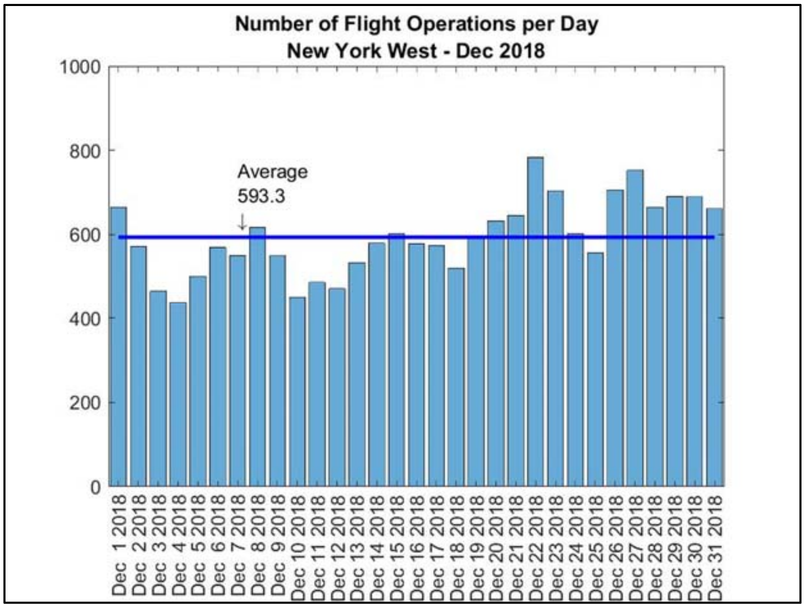

Figure 2-2. Number of Flight Operations Observed by Day – New York West FIR December 2018

3. RVSM Airspace Audit

3.1 The December 2018 traffic sample data (TSD) obtained from the ATOP DR&A for the New York FIR are used to identify flight operations within RVSM airspace. These data show 19,453 flight operations in the month of December 2018 within the New York West FIR. An RVSM airspace audit for the Miami Oceanic and San Juan FIRs is not possible because the TFMS data collected for that airspace does not contain aircraft registration marks.

3.2 The December 2018 TSD for the New York West FIR was compared with the collective RVSM approvals database as of 30 September 2019 to determine the approval status of each observed operation. There were eight operator-aircraft pairs from four States and three RMAs that indicated RVSM approval in the filed flight plan for which an RVSM approval could not be found. This audit is performed routinely to identify operations incorrectly filing RVSM approval in their flight plans. **Table 3-1** contains the details of these results.

Table 3-1. RVSM Airspace Audit Results December 2018

STATE	REG	ACID	ACT	COUNT	RMA
Brazil	PROCJ	ONE8501	A332	3	CARSAMMA
Mexico	XARBI	XARBI	F900	3	NAARMO
Mexico	XALRM	XALRM	H25C	3	NAARMO
United States	N604BL	N604BL		2	NAARMO
United States	N880VJ	N880VJ	F2TH	2	NAARMO
Russia	RANGR72	RANGR72	C130	2	EURASIA RMA
United States	N505GD	N505GD	GA5C	2	NAARMO
United States	N600G	N600G	GA6C	2	NAARMO

4. Reported Large Height Deviations (LHDs)

4.1 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 132 reported events during calendar year 2018 identified within the Miami Oceanic, New York West, and San Juan airspace. These events were reviewed by the scrutiny group. The scrutiny group consists of operational experts from each air traffic control facility and safety analyses experts from the NAARMO. After scrutiny group review, twenty-four of the reported events were determined to be vertical risk-bearing LHDs. **Table 4-1** contains a summary of all the risk-bearing LHDs by month.

Table 4-1. Risk-bearing LHDs – 2018

Month	Count	Duration at Unexpected FL (mins)	Number of Unexpected FLs Crossed
Jan-18	3	8	13
Feb-18	1	4	0
Mar-18	2	0	0
Apr-18	2	18	0
May-18	2	2	1
Jun-18	2	6	0
Jul-18	3	17	1
Aug-18	3	39	0
Sep-18	1	0	7
Oct-18	3	11	0
Nov-18	1	0	0
Dec-18	1	0	0
TOTAL	**24**	**105.0**	**22**

4.2 The scrutiny review determined a general cause for each of the twenty-four risk-bearing LHD reports in 2018. **Table 4-2** summarizes the risk-bearing reported LHDs categorized by general cause.

Table 4-2. Risk-bearing LHD Reports by Cause – 2018

LHD Category Code	LHD Category Description	Number of LHD	Duration at Unexpected FL (minutes)	Number of Unexpected FLs Crossed
A	Flight crew failing to climb / descend the aircraft as cleared	0	0	0
B	Flight crew climbing /descending without ATC clearance	8	9	22
C	Incorrect operation of airborne equipment	1	35	0

LHD Category Code	LHD Category Description	Number of LHD	Duration at Unexpected FL (minutes)	Number of Unexpected FLs Crossed
D	ATC system loop error; (e.g., ATC issues incorrect clearance or flight crew misunderstands clearance message)	2	29	0
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility as a result of human factors issues	7	32	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	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 – did not adhere to Wx contingency procedure	4	0	0
	TOTAL	**24**	**105**	**22**

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

4.4 **Figure 4-1** shows the comparison in number of risk-bearing LHD reports observed in 2018 with the 2017 results by LHD category. The vertical axis shows the observed counts within each LHD category. There were more qualifying reported LHDs in 2018 compared to 2017, 24 risk-bearing LHD reports in 2018 compared to 19 risk-bearing LHD reports in 2017. The categories in which the number of risk-bearing reports had observed increases were in the pilot climb/descend without clearance (category B), and other (category M). All four reported LHDs classified as category M, Other, involve the incorrect application of weather deviation procedures. In these cases, an LHD was recorded for the aircrew failing to change altitude by +/- 300ft in accordance with the procedure.

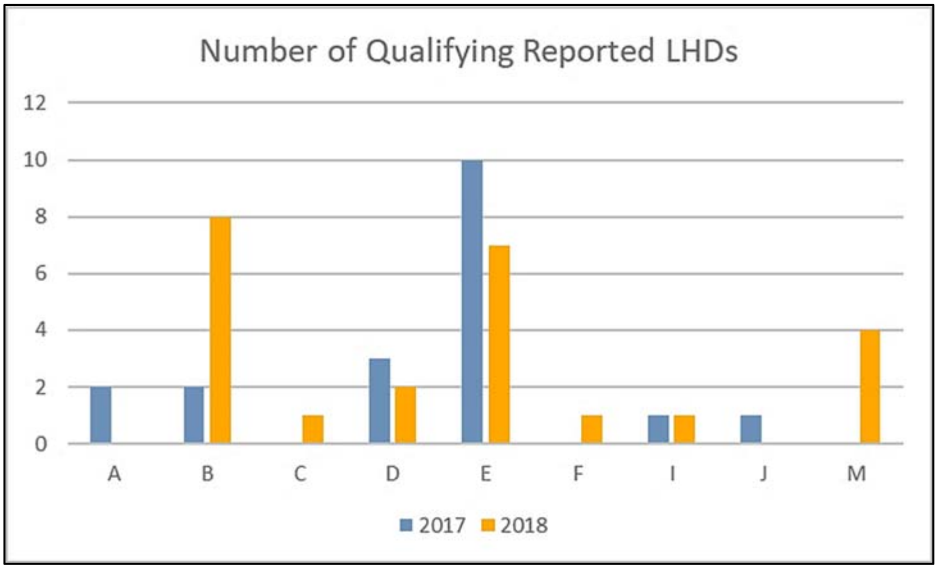

Figure 4-1. Number of reported risk-bearing LHDs by category code, 2018 vs 2017

4.5 **Figure 4-2** shows the comparison of the associated duration for reported LHDs in 2018 with the 2017 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 reported ATC-to-ATC transition errors (category E) in 2018 compared to 2017. The event with category code 'C', incorrect interpretation of airborne equipment, involved an air crew providing an altitude report that was in accordance with a conditional clearance but not accurate with the aircraft position.

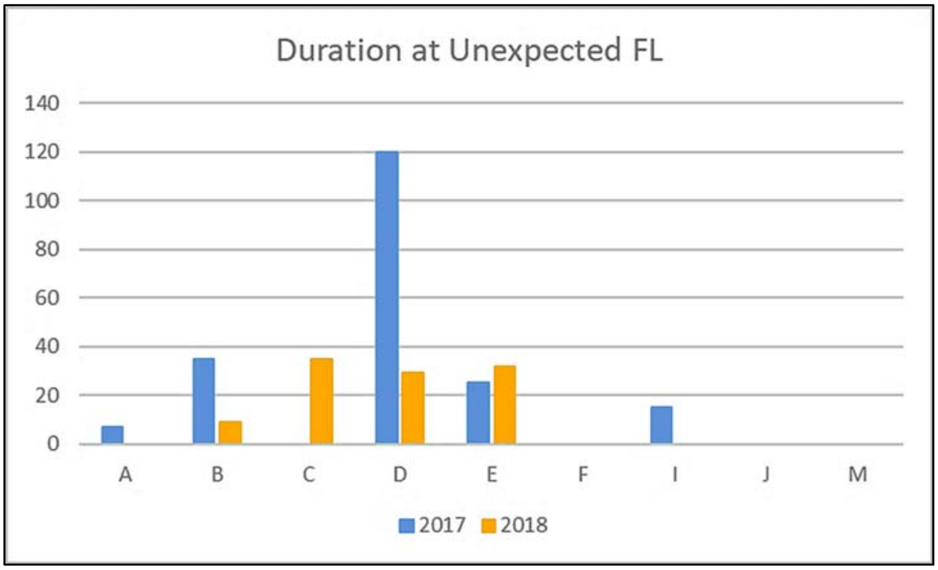

Figure 4-2. Duration at unexpected/incorrect FL (minutes) by LHD category, 2018 vs 2017

4.6 The definition of a long duration LHD is one with a duration of twenty or more minutes. There was one reported long duration LHD in 2018. The category code for this event was 'C', incorrect interpretation of airborne equipment. In this case, the aircrew had received a conditional clearance to reach a higher FL by a given airspace fix. However, the aircrew reported level at the new FL via High

Frequency (HF) radio prior to actually reaching the new FL. The scrutiny group estimated the time for which ATC protected only the new FL, but for which the aircrew were occupying the old FL, to be thirty-five minutes.

4.7 The reported LHD with category code 'I' involved turbulence. This reported LHD is attributed towards technical risk not operational risk. There was no location information or deviation magnitude specified in the report.

4.8 One operational mitigation developed from the reported LHDs is a change to the automated alerts when an altitude range change (ARC) event is observed. An ARC event contract is used for aircraft reporting position via Automatic Dependent Surveillance – Contract (ADS-C). The ARC allows ATC to set a range around the cleared flight level. Prior to this change, the ARC range was set to +/- 200ft of the cleared flight level. For example, for a cleared FL of F330 the ARC event contract range would have been set to 33200 – 31800. If the observed FL was outside of this range, an automatic message would be sent from the aircraft to ATC as a FL change alert. However, the automation system does not notify ATC of altitude changes within 200ft of the cleared FL. Therefore, the mitigation developed to improve alerting to ATC is to change the ARC range from +/- 200ft to +/- 212ft. Any ARC message received for FL differences greater than 200ft will update the data block and alert ATC for action.

4.9 The 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 4-3 contains the breakdown of risk-bearing LHD events and associated durations for each area.

Table 4-3. Risk-bearing LHD Reports by Area – 2018

Airspace	Number of LHD	Duration at unexpected FL (min)	Number of unexpected FLs crossed
Miami Oceanic/San Juan FIRs and New York West boundary	9	43	7
New York West FIR	15	62	15

Figure 4-3 shows the approximate locations of the risk-bearing LHDs in 2018. 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.

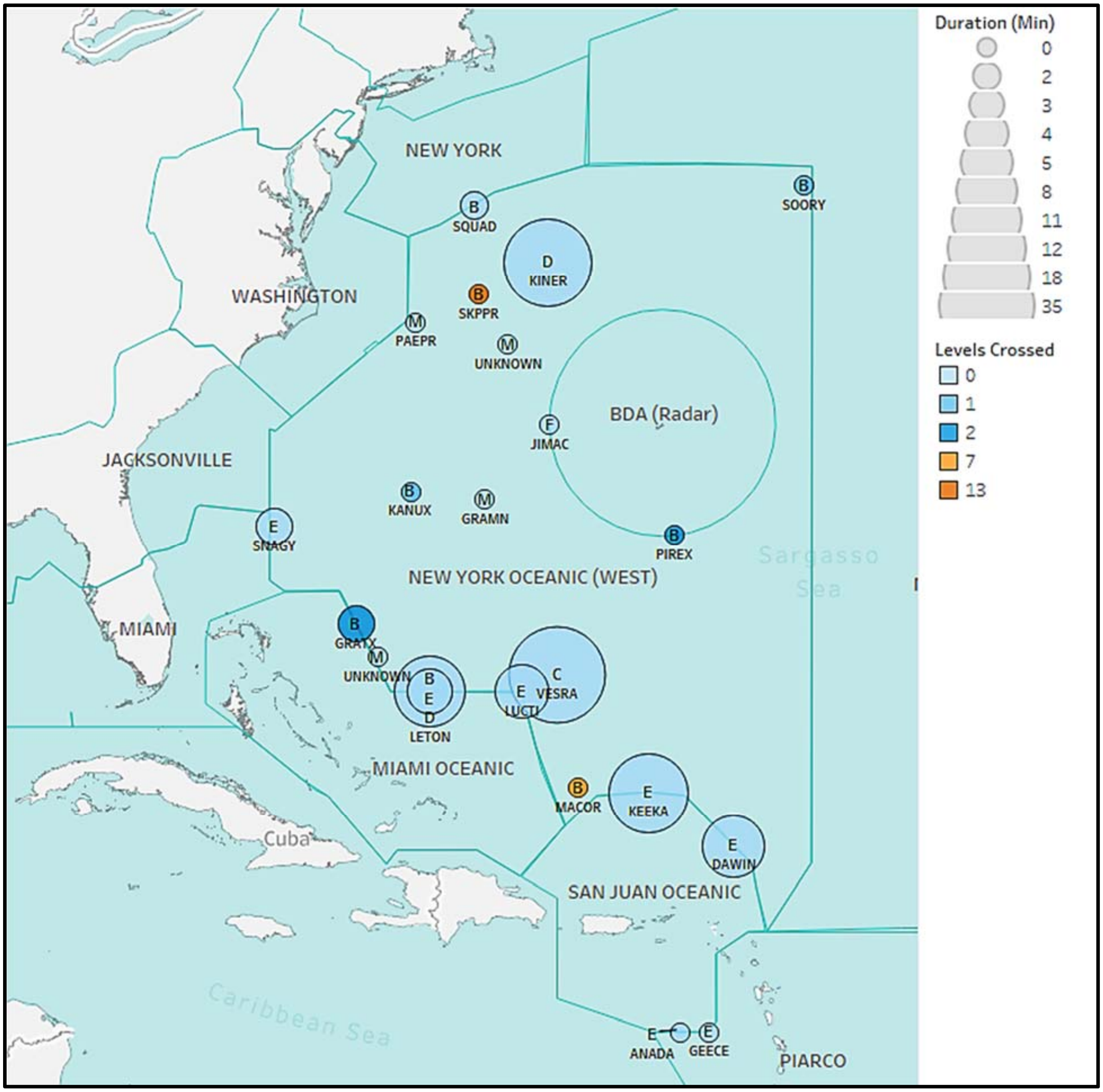

Figure 4-3. Approximate Location of the Risk-bearing LHDs - 2018

4.10 The NAARMO organized scrutiny-group teleconferences between the various ATC facilities to review the events reported during 2018. However, the scrutiny review took place several months after the end of the calendar year. This time lapse did not permit the scrutiny team to obtain responses from the aircraft operators and limited any additional information from ANSPs. As the available resources allow, the NAARMO will arrange for scrutiny meetings earlier in the calendar year.

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 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.

5.3 Based on the December 2018 traffic data, the NAARMO estimates approximately 598,777 annual flying hours for 2018 in Miami Oceanic, New York West, and San Juan airspace where the RVSM is applied.

5.4 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.

5.5 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:

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

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 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.

5.6 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.

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

5.7.1 **Figure 5-1** provides the top 15 aircraft types observed in the December 2018 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 5-1** account for more than 80 percent of total flying hours observed in the airspace. The flying hours associated with the Boeing 737-800 aircraft type represent 13 percent of all the flying hours observed in the traffic sample. 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 23 percent of all the flying hours observed in the traffic data.

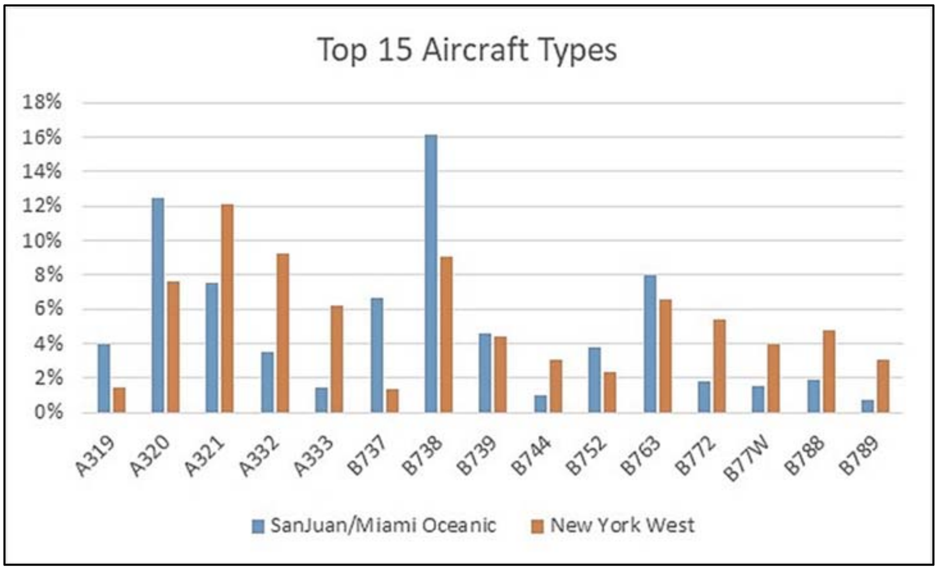

Figure 5-1. Observed Aircraft Types in Terms of Flying Hours in Miami Oceanic/San Juan and New York West Airspace

5.8 *Aircraft Size*

5.8.1 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 2018 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 5-1**.

Table 5-1. CRM Parameter Estimates for Aircraft Size

Airspace	Length λ_x (NM)	Wingspan λ_y (NM)	Height λ_z (NM)
Miami Oceanic/San Juan	0.0232 *(141 ft)*	0.0213 *(130 ft)*	0.0070 *(43 ft)*
New York West	0.0281 *(170 ft)*	0.0260 *(158 ft)*	0.0080 *(49 ft)*

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

5.9.1 The traffic data are used to estimate the vertical occupancy values for the airspace. **Table 5-2** 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 2018 is approximately the same as the value estimated in 2017. The opposite direction vertical occupancy value for New York West airspace for 2018 is 15 percent higher than the value estimated in 2017.

Table 5-2. Same and Opposite direction vertical occupancy estimates

Airspace	Same Direction Vertical Occupancy Value	Opposite Direction Vertical Occupancy Value
Miami Oceanic and San Juan	0.0291	0.0945
New York West	0.0452	0.0855

5.9.2 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 2018 data was 5,361. This value, prorated from the 31-sample days for the calendar year 2018, is 64,334 aircraft pairs annually.

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

5.10.1 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.

5.10.2 Currently, the U.S. Aircraft Geometric Height Measurement Element (AGHME) and the GPS Monitoring Unit (GMU) systems provide the NAARMO with estimates of aircraft altimetry system error (ASE), an important contributor to estimated risk. Control of ASE is one of the principal objectives of the State RVSM approval process, and State RVSM approvals must be held by operators in airspace where the RVSM is applied.

5.10.3 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.

5.11 *Time spent at Unexpected FL*

5.11.1 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 2018 contain 105 minutes of flying time spent at unexpected flight level.

5.11.2 **Table 4-3** (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 305,207 hours. The estimated annual flying hours for Miami Oceanic and San Juan airspace obtained from the combined TFMS data are 293,571 flying hours. The ratios of time spent at unexpected flight level are 3.38×10^{-6} and 2.44×10^{-6} for New York West and Miami Oceanic/San Juan airspace, respectively.

5.12 *Collision Risk Model Parameters*

5.12.1 The individual parameters of the models, their definitions, estimates, and sources are given in **Table 5-3**.

Table 5-3. 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
$P_y(0)$	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.	0.0232 NM and 0.0281 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data

Term	Definition	Estimate	Source
λ_y	Average aircraft wingspan.	0.0213 NM and 0.0260 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_z	Average aircraft height with undercarriage retracted.	0.0070 NM and 0.0080 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.	0.029 and 0.045	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.	0.094 and 0.085	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	305,207	Estimated from FAA ATOP DR&A for New York West airspace
F(MS)	Estimated flying hours within Miami Oceanic and San Juan FIRs	293,571	Estimated from TFMS data for Miami Oceanic and San Juan airspace

6. Results and Conclusions

6.1 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 6-1** provides the weighted 2018 estimates of technical and operational vertical risk for Miami Oceanic, New York West and San Juan airspace. The last row in **Table 6-1** contains the weighted sum of the risk from the two areas.

Table 6-1. 2018 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	0.03	27.04	27.07
Miami Oceanic and San Juan	0.04	21.00	21.04
Total	**0.07**	**48.04**	**48.11**

6.2 The estimated technical risk in the 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 vertical risk estimate for RVSM airspace 48.04 × 10^{-9} fapfh. The sum of this value and the technical risk estimate for airspace is 48.11 × 10^{-9} fapfh, or eight times greater than the overall safety goal of 5.0 × 10^{-9} fapfh. The reported LHD with the longest duration, 35 minutes, contributes thirty percent of the overall estimated vertical collision risk, or 14.4 × 10^{-9} fapfh. The category E reported LHDs contribute thirty percent of the overall estimated vertical collision risk, or 14.8 × 10^{-9} fapfh.

6.4 The estimated vertical risk estimate for 2018, shown in **Table 6-1**, is lower than the estimates for 2017 and 2016. The overall vertical risk estimates in in 2017 and 2016 were 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 —