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(GTE/21)**

Zoom Meeting, 23 – 26 August 2021

Agenda Item 2: Review of the Results of Large Height Deviation (LHD) Analysis

**VERTICAL SAFETY MONITORING REPORT FOR MIAMI OCEANIC, NEW YORK WEST,
AND SAN JUAN AIRSPACE – 2020**

(Presented by NAARMO)

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 2020.

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 2020. There are 16 reported events accounting for 20 minutes spent at an unexpected/incorrect Flight Level (FL) during calendar year 2020. This report also contains an estimate of the vertical collision risk. The vertical collision risk estimate for the airspace slightly exceeds the Target Level of Safety (TLS) value of 5.0×10^{-9} fatal accidents per flight hour.

Action:	Described in Section 3
<i>Strategic Objectives:</i>	<ul style="list-style-type: none">• Safety• Air Navigation Capacity and Efficiency
<i>References:</i>	<ul style="list-style-type: none">• 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 Air Traffic Service (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.

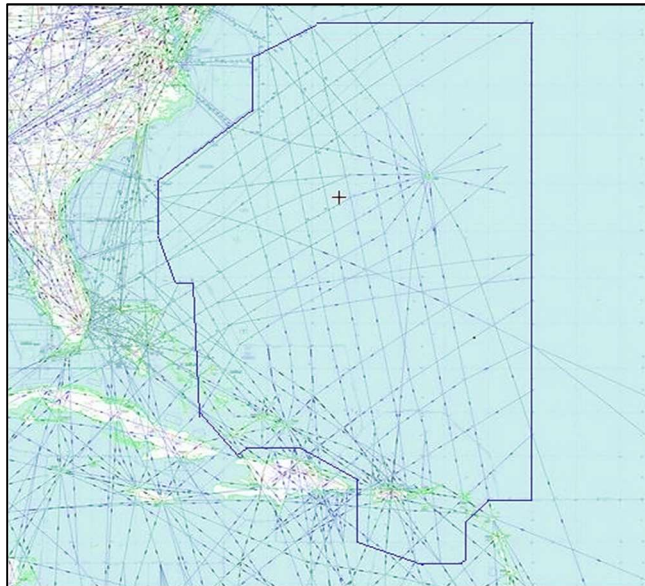


Figure 1-1. Miami Oceanic, New York West, San Juan FIRs

1.3 This report covers the calendar year 2020. 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 40 such reports submitted to the NAARMO for calendar year 2020.

2. Discussion

2.1 *Traffic Sample Data*

2.1.1 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.

2.1.2 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 2020. 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

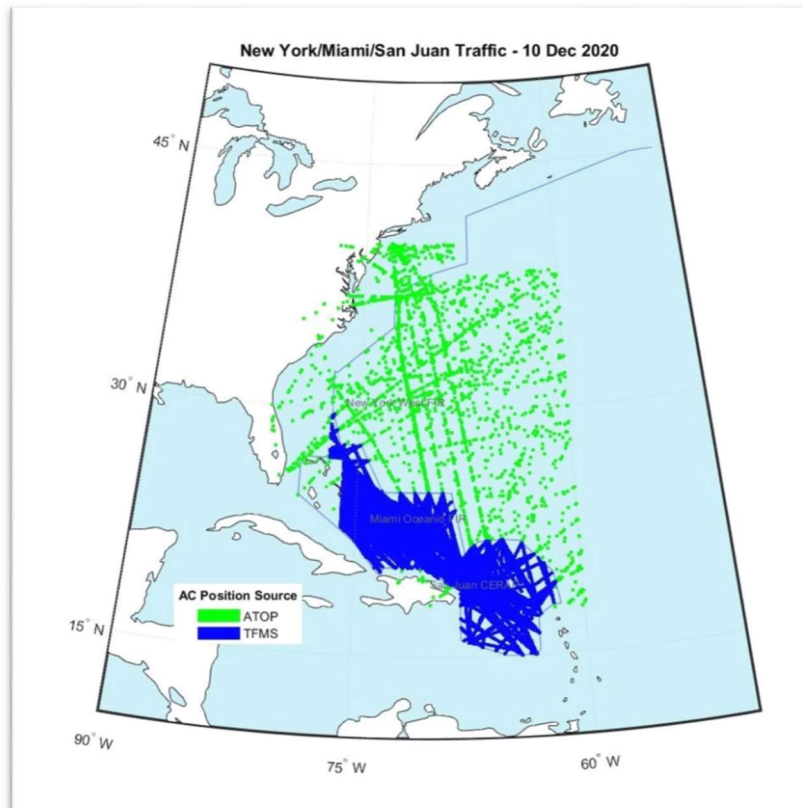


Figure 2-1. Miami Oceanic, New York West, San Juan FIRs Air Traffic Operations – 10 Dec 2020

2.1.3 Figure 2-2 shows the number of flight operations per month for the New York West FIR for calendar year 2020. The vertical bars represent the total number of flight operations observed each month during calendar year 2020. The average number of flight operations per day varies by month due to the COVID-19 pandemic and the associated reduction in air travel during 2020. In January 2020, the average number of flight operations per day was more than 700 in the New York West FIR. In April 2020, the average number of flight operations per day was less than 60 flight operations.

2.1.4 In normal times, seasonal variations in traffic volume are expected. Typically, the high traffic period for Miami Oceanic, New York West, and San Juan airspace begins in November and ends in April/May. Figure 2-2 shows that by the end of calendar year 2020, traffic levels are increasing; in December 2020, the average number of flight operations per day reached 400 flight operations.

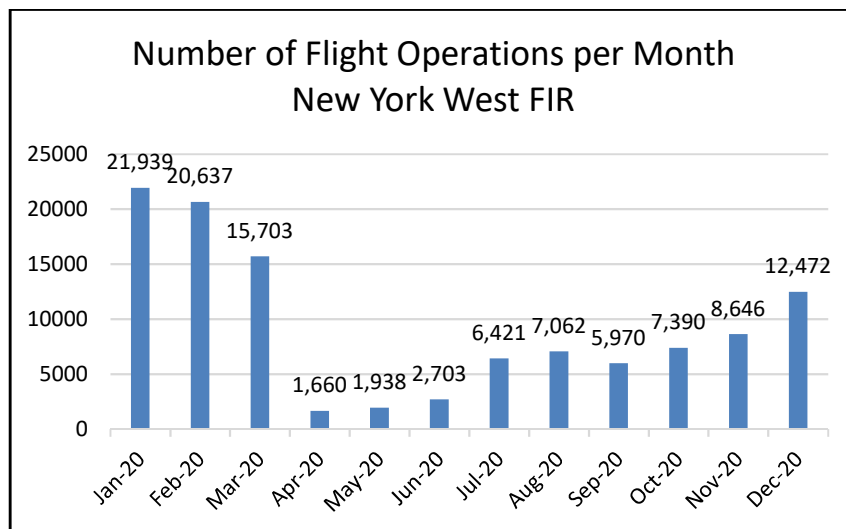


Figure 2-2. New York West FIR, Number of flight operations per month – calendar year 2020

2.2 *Reported Large Height Deviations (LHDs)*

2.2.1 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 40 reported occurrences 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, representatives from FAA Flight Standards and Airspace Safety, and safety analyses experts from the NAARMO. The scrutiny group met virtually seven times and reviewed all forty reported occurrences from calendar year 2020. Resulting from the work of the scrutiny group, there are sixteen reported LHD occurrences during calendar year 2020. Table 2-1 contains a summary of all the risk-bearing LHDs by month

Table 2-1. Risk-bearing LHDs – 2020

Month	Count	Duration at Unexpected FL (mins)	Number of Unexpected FLs Crossed
Jan-20	3	3	2
Feb-20	2	1	0
Mar-20	3	5	2
Apr-20	0	0	0
May-20	0	0	0
Jun-20	1	0	0
Jul-20	1	0	0
Aug-20	0	0	0
Sep-20	1	0	0
Oct-20	0	0	0
Nov-20	3	10	1
Dec-20	2	1	0
TOTAL	16	20	5

2.2.2 The scrutiny group review determined a general cause for each of the risk-bearing LHD reports in 2020. Table 2-2 summarizes the risk-bearing reported LHDs categorized by general cause. Four of the sixteen reported LHDs listed in Table 2-2 are classified as Technical Risk. The technical risk LHDs include the two category J and two category L events. The associated duration and/or flight levels crossed for the technical risk LHDs are not included in Tables 2-1 and 2-2. Only the operational risk LHDs contribute to the duration at incorrect FL and number of incorrect FLs crossed in Tables 2-1 and 2-2.

Table 2-2. Risk-bearing LHD Reports by Cause – 2020

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	2	2	2
B	Flight crew climbing /descending without ATC clearance	3	9	3
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)	3	7	0
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility as a result of human factors issues	3	2	0
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues	0	0	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level	1	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	0	0	0
J	TCAS resolution advisory; flight crew correctly following the resolution advisory	2	0	0
K	TCAS resolution advisory; flight crew incorrectly following the resolution advisory	0	0	0
L	An aircraft being provided with RVSM separation is not RVSM approved (e.g. flight plan indicating RVSM approval but aircraft not approved, ATC misinterpretation of flight plan)	2	0	0
M	Other	0	0	0
	TOTAL	16	20	5

2.2.3 A decrease in both the number of reported LHDs and duration spent at the unexpected/incorrect FL was observed in 2020 compared to the previous years. This result was expected due to the COVID-19 pandemic and the associated reduction in air travel during 2020. Figure 2-3 shows the observed decrease in the numbers of reported LHDs was 38 percent, the observed decrease in time spent at incorrect flight levels was 56 percent, and the decrease in the number flight levels crossed incorrectly was 58 percent for calendar year 2020 compared to 2019.

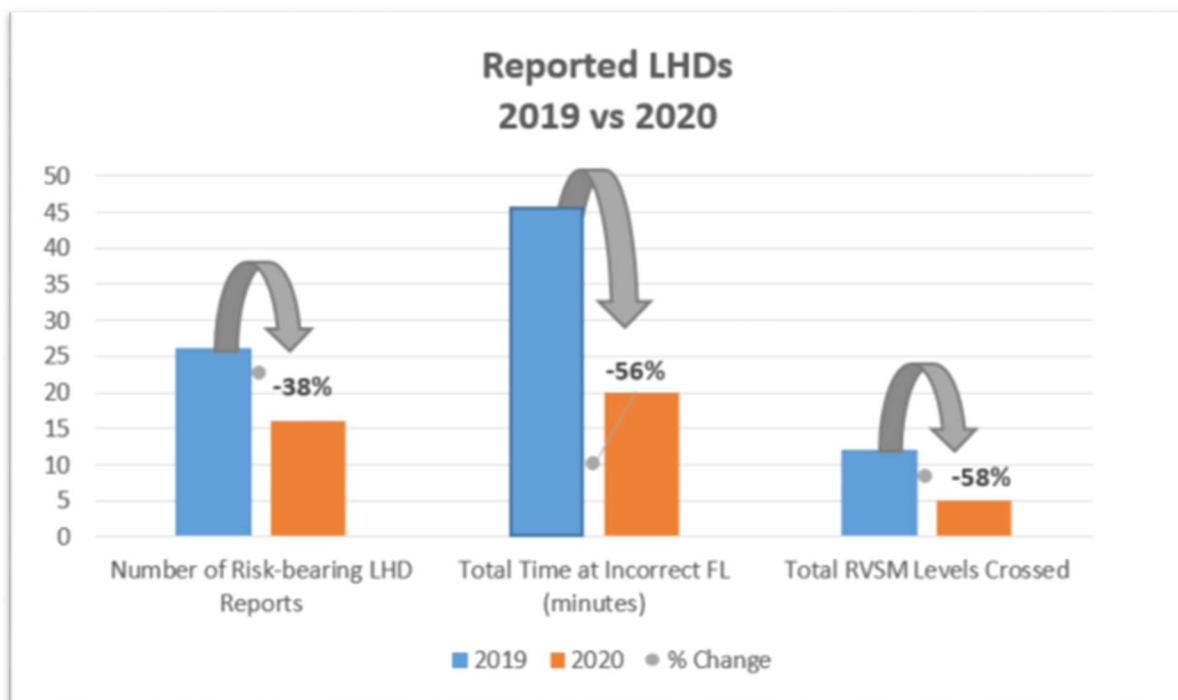


Figure 2-3. Reported LHDs, 2019 vs 2020

2.2.4 There was a slight increase in the number of reported LHDs involving the transfer of ATC control. There are three category E events. In addition, the three category D events indicate that category E was a secondary causal factor. This yields six reported LHDs involving the transfer of ATC control with a total of nine minutes of operation at unexpected FLs. During the scrutiny reviews, ATC operational experts indicated these category E occurrences are discussed during routine teleconferences attended by representatives from the adjacent facilities. For example, the Miami, Houston, and Havana ATC centers have a weekly automatic data exchange (ADE) teleconference that provides opportunities to discuss related issues.

2.2.5 There were two reported category A LHDs that were caused by misunderstanding of CPDLC conditional clearances. The total time spent at incorrect flight level was two minutes and two flight levels crossed incorrectly.

2.2.6 There were three reported category B LHDs. One of these reported LHDs involved a HF flight operation that climbed without ATC clearance to avoid weather. For this occurrence, non-operational Automatic Dependent Surveillance – Broadcast (ADS-B) data were available to identify nine minutes at an incorrect FL and one flight level crossed without ATC clearance.

2.2.7 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 2-3 contains the breakdown of risk-bearing LHD events and associated durations for each area. Figure 2-4 shows the approximate locations of the risk-bearing LHDs in 2020. The locations of the category E and F events occur on an ATC boundary.

Table 2-3. Operational Risk-bearing Reported LHDs by Area – 2020

Table 2-3. Operational Risk-bearing Reported LHDs by Area – 2020

Airspace	Number of LHD	Duration at unexpected FL (min)	Number of unexpected FLs crossed
Miami Oceanic/San Juan FIRs and New York West boundary	5	2	2
New York West FIR	7	18	3
Total	12	20	5

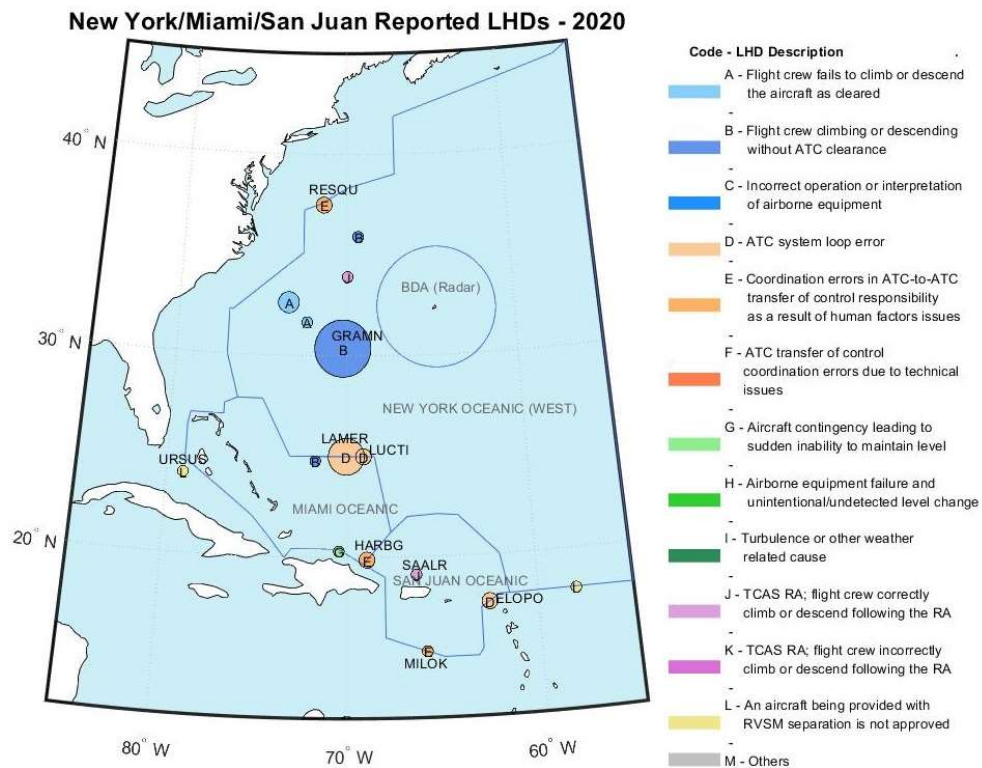


Figure 2-4. Approximate Location of the Risk-bearing LHDs – 2020

2.2.8 For comparison, a summary of the reported LHDs for the New York West, Miami Oceanic and San Juan airspace during calendar years 2017 through 2020 is shown in Figure 2-5. Although the numbers of reported LHDs remains somewhat constant, the associated LHD durations have decreased during the period. One reason for this decrease results from the implemented changes to the automation systems. Also, for data link operations in New York West airspace, ATC receives alerts for climbs/descends without or not according to ATC clearance. The available surveillance in the Miami Oceanic and San Juan areas also provide alerts to ATC for unexpected climbs/descends.

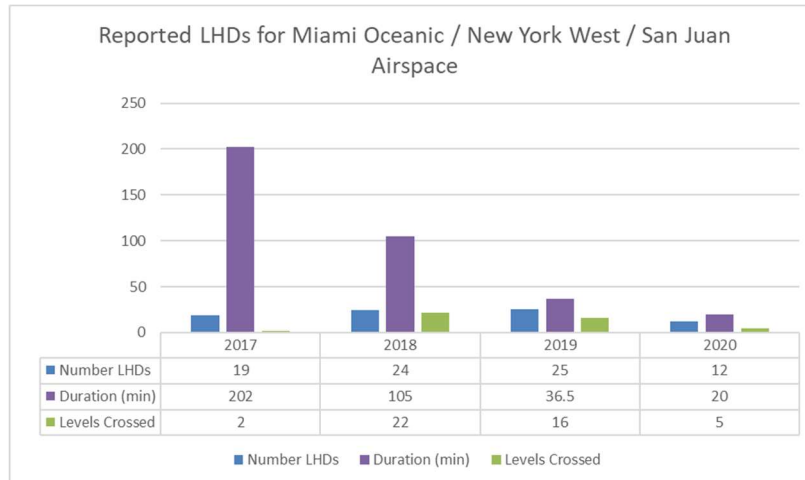


Figure 2-5. Reported LHD Trends, 2017 through 2020

2.2.9 Vertical Collision Risk Estimation

2.2.10 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.

2.2.11 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 with 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:

2.2.12 Collision risk due to all causes does not exceed 5 fatal accidents in 109 flying hours, and, simultaneously,

2.2.13 Collision risk due to aircraft height-keeping systems does not exceed 2.5 fatal accidents in 109 flying hours

2.2.14 Based on the December 2020 traffic data, the NAARMO estimates approximately 399,156 annual flying hours for 2020 in Miami Oceanic, New York West, and San Juan airspace where the RVSM is applied. This represents an average 35 percent decrease in flying hours compared to 2019.

2.2.15 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.

2.2.16 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:

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

2.2.17 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. Where the 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.

2.2.18 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.

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

2.2.20 Figure 2-6 provides the top aircraft types observed in the December 2020 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 2-6 account for more than 70 percent of total flying hours observed in the airspace. The Airbus A320 is the 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 27 percent of all the flying hours observed in the traffic data. The second most frequently observed aircraft is the Boeing 737 NGX family; including the B737, B738 and B739. The percentage of flying hours for the Boeing 737 NGX family is more than 14 percent of all flying hours observed in the traffic data.

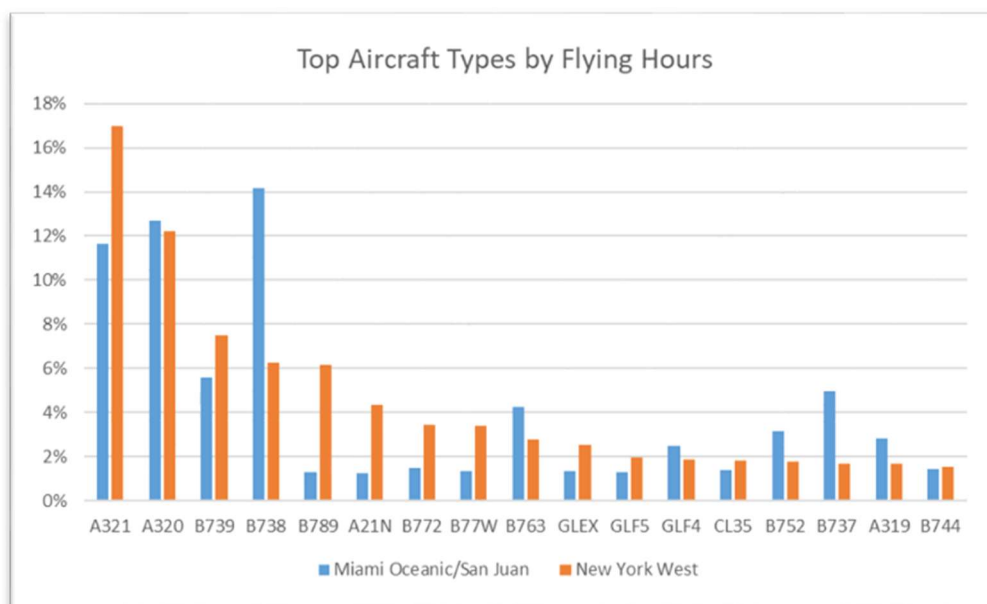


Figure 2-6. Observed Aircraft Types in Terms of Flying Hours in Miami Oceanic/San Juan and New York West Airspace - 2020

2.2.21 Aircraft Size

2.2.22 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 2020 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 2-4.

Table 2-4. CRM Parameter Estimates for Aircraft Size

Airspace	Length λ_x (NM)	Wingspan λ_y (NM)	Height λ_z (NM)
Miami Oceanic/San Juan	0.0219 <i>(133 ft)</i>	0.0194 <i>(118 ft)</i>	0.0065 <i>(40 ft)</i>
New York West	0.0243 <i>(148 ft)</i>	0.0217 <i>(132 ft)</i>	0.0069 <i>(42 ft)</i>

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

2.2.24 The traffic data are used to estimate the vertical occupancy values for the airspace. Table 2-5 shows the same and opposite direction vertical occupancy estimates for the Miami Oceanic/San Juan and New York West airspace.

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

Airspace	Same Direction Vertical Occupancy Value	Opposite Direction Vertical Occupancy Value
Miami Oceanic and San Juan	0.0298	0.0773
New York West	0.0169	0.0988

2.2.25 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 2020 traffic sample from Miami Oceanic and San Juan airspace was 4,953. This value, prorated from the 31-sample days for the calendar year 2020, is 58,317 aircraft pairs annually.

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

2.2.27 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.

2.2.28 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), 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.

2.2.29 The NAARMO estimate for the probability of vertical overlap for aircraft pairs operating on adjacent flight levels, $P_z(1000)$, 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.

2.2.30 *Time spent at Unexpected/Incorrect FL*

2.2.31 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 2020 contain 20 minutes of flying time spent at unexpected flight level.

2.2.32 Table 2-3, provided earlier in this paper, gives 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 170,094 hours. The estimated annual flying hours for Miami Oceanic and San Juan airspace obtained from the combined TFMS data are 229,062 flying hours. The ratios of time spent at unexpected flight level are 1.8×10^{-6} and 1.5×10^{-7} for New York West and Miami Oceanic/San Juan airspace, respectively.

2.2.33 *Collision Risk Model Parameters*

2.2.34 The individual parameters of the models, their definitions, estimates, and sources are given in Table 2-6.

Table 2-6. 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.	0.0219 NM and 0.0244 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_y	Average aircraft wingspan.	0.0194 NM and 0.0217 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_z	Average aircraft height with undercarriage retracted.	0.0065 NM and 0.0069 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
$E_z(\text{same})$	Same-direction vertical occupancy for a pair of aircraft at adjacent flight levels on same route.	0.030 and 0.017	Estimated from Miami Oceanic/San Juan and New York West traffic data
$E_z(\text{opp})$	Opposite-direction vertical occupancy for a pair of aircraft at adjacent flight levels on same route.	0.077 and 0.098	Estimated from Miami Oceanic/San Juan and New York West traffic data
$ \overline{\Delta V} $	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{V} $	Average absolute aircraft ground speed.	480 knots	Value used in the North Atlantic, Pacific, and US Domestic airspace vertical risk estimates
$ \overline{y} $	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{z} $	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	170,094	Estimated from FAA ATOP DR&A for New York West airspace
$F(MS)$	Estimated flying hours within Miami Oceanic and San Juan FIRs	229,062	Estimated from TFMS data for Miami Oceanic and San Juan airspace

2.2.36 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 2-7 provides the weighted 2020 estimates of technical and operational vertical risk for Miami Oceanic, New York West and San Juan airspace. The last row in Table 2-7 contains the weighted sum of the risk from the two areas.

Table 2-7. 2020 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	3.89	3.93
Miami Oceanic and San Juan	0.03	1.72	1.75
Total	0.07	5.61	5.68

2.2.37 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.

2.2.38 The operational vertical risk estimate for RVSM airspace 5.61×10^{-9} fapfh. The sum of this value and the technical risk estimate for airspace is 5.68×10^{-9} fapfh, or slightly larger than the overall safety goal of 5.0×10^{-9} fapfh.

2.2.39 The estimated vertical risk estimate for 2020, shown in Table 2-7, is lower than the estimates for previous four year period (e.g. 2016 – 2019). The decrease in the vertical risk estimate is directly related to the decrease in the time spent at unexpected flight levels as shown earlier in Figure 2-5. The current trend shows smaller LHD durations as improvements are made to ATC automation systems. Also, for data link operations in New York West airspace, ATC receives early alerts for climbs/descends without or not according to ATC clearance. The available surveillance in the Miami Oceanic and San Juan areas also provide alerts to ATC for unexpected climbs/descends. The reduced numbers of operations associated with the COVID-19 pandemic during calendar year 2020 was also a factor in the number of reported occurrences for this year.

3 Action by the meeting

3.1 The Meeting is invited to note and discuss the information provided.