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CAR/SAM Planning and Implementation Regional Group (GREPECAS) Eighteenth Scrutiny Working Group Meeting (GTE/18)
Mexico City, Mexico, 22 – 26 October 2018

Agenda Item 3: Large Height Deviation (LHD) analysis

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

(Presented by United States/
North American Approvals Registry and Monitoring Organization (NAARMO))

EXECUTIVE SUMMARY

This Information Paper presents the 2017 vertical safety monitoring report for the Miami Oceanic, New York West, and San Juan airspace. The purpose of this report is to compare actual performance to safety goals related to continued use of the Reduced Vertical Separation Minimum (RVSM) in Miami Oceanic, New York West, and San Juan Airspace. This report contains a summary of Large Height Deviation (LHD) reports received by the NAARMO for the calendar year 2017. There are 122 reported events accounting for 202 minutes spent at an uncleared / incorrect flight level during calendar year 2017. 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 • Air Navigation Capacity and Efficiency

1. Introduction

1.1 The North American Approvals Registry and Monitoring Organization (NAARMO), a service provided by the FAA Technical Center, fulfils the role of regional monitoring agency (RMA) for the continued-safe use of the Reduced Vertical Separation Minimum (RVSM) in the Miami Oceanic, New York West, and San Juan airspace.

1.2 The **attached** report contains a summary of Large Height Deviation (LHD) reports received by the NAARMO for the calendar year 2017. There are 122 reported events accounting for 202 minutes spent at an uncleared/incorrect flight level during calendar year 2017. The attached 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.

3. Action

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

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APPENDIX

MIAMI OCEANIC, NEW YORK WEST, AND SAN JUAN AIRSPACE VERTICAL SAFETY MONITORING REPORT ~ 2017

September 2018

Vertical Safety Monitoring Report for Miami Oceanic, New York West, and San Juan Airspace

(Prepared by North American Approvals Registry and Monitoring Organization (NAARMO))

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 2017.

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 2017. There are 122 reported events accounting for 202 minutes spent at an uncleared / incorrect flight level during calendar year 2017. 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.

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.

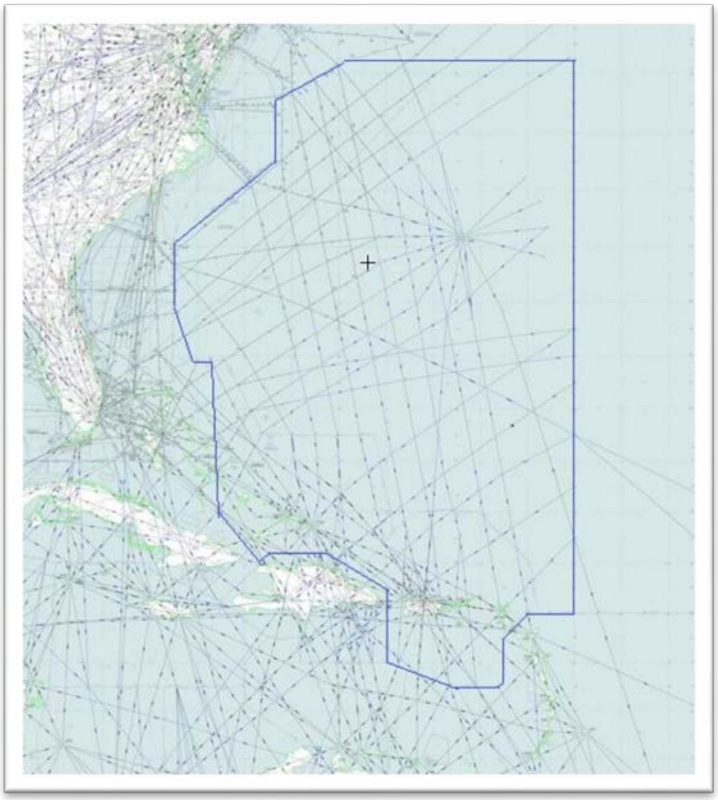

Figure 1-1. Miami Oceanic, New York West, San Juan FIRs

1.3. This report covers the calendar year 2017. 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 122 such reports submitted to the NAARMO for calendar year 2017.

1.4. The airspace referenced in this report is larger than the airspace considered in the report for the previous calendar year. The vertical report for calendar year 2016 considered the reported events and traffic data for the New York West FIR only. The current report expands the analyses to include the reported events and traffic data from the Miami Oceanic and San Juan FIRs along with the data collected for the New York West FIR. Therefore, it may not be possible to make direct comparisons to the results observed for previous years.

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. **Figure 2-1** presents the aircraft positions provided in the Miami Oceanic and San Juan TFMS data for 1 December 2017.

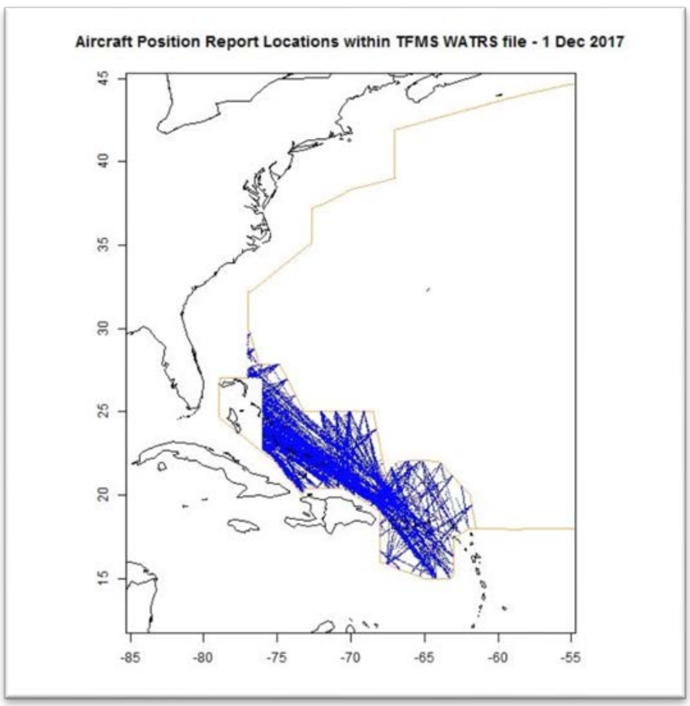

Figure 2-1. Aircraft Position Data Provided in TFMS – 1 December 2017

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 2-2** shows the positions within the New York West FIR during December 2017.

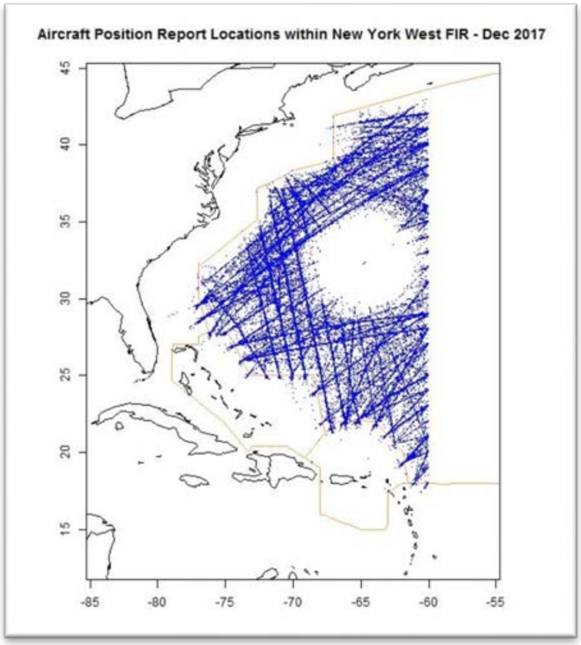

Figure 2-2. Aircraft Position Data Provided in ATOP DR&A - December 2017

2.3. 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.

2.4. **Figure 2-3** shows the number of flights by day in the New York West FIR for December 2017. 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 553 flights per day.

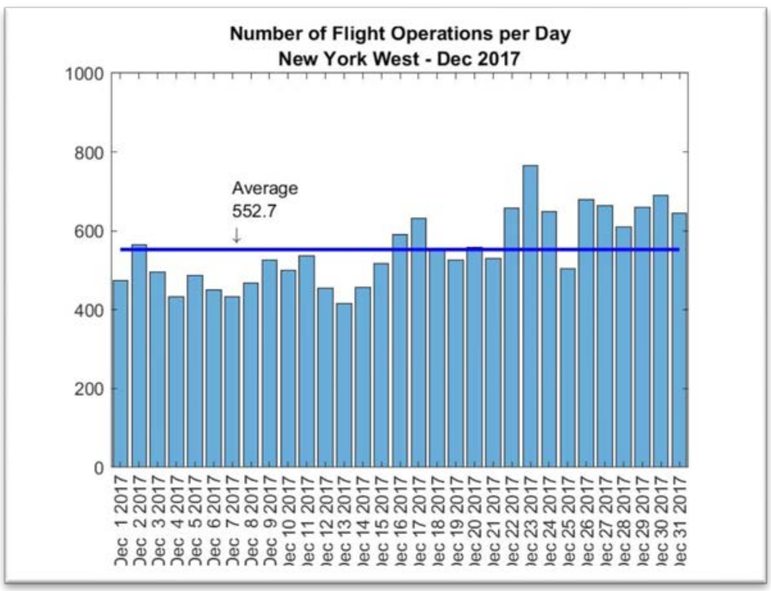

Figure 2-3. Number of Flight Operations Observed by Day – New York West FIR December 2017

3. RVSM Airspace Audit

3.1. The December 2017 traffic sample data obtained from the ATOP DR&A for the New York FIR are used to identify the operations within RVSM airspace. These data show 17,106 operations in the month of December 2017 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 2017 TSD for the New York West FIR was compared with the collective RVSM approvals database as of 30 August 2018 to determine the approval status of each observed operation. There were zero operations that indicated RVSM approval for which an approval could not be found. This audit is performed routinely to identify operations incorrectly filing RVSM approval in their flight plans.

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 122 reported events during calendar year 2017 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, 19 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 - 2017

Month	Count	Duration at Uncleared FL (mins)	Number of Uncleared FLs Crossed
Jan-17	2	45.0	0
Feb-17	3	47.0	0
Mar-17	2	2.0	0
Apr-17	1	1.0	0
May-17	1	6.0	0
Jun-17	1	3.0	0
Jul-17	2	1.0	2
Aug-17	3	70.0	0
Sep-17	1	6.0	0
Oct-17	0	0.0	0
Nov-17	0	0.0	0
Dec-17	3	21.0	0
TOTAL	**19**	**202.0**	**2**

4.2. The scrutiny review determined a general cause for each of the 19 risk-bearing LHD reports in 2017. **Table 4-2** summarizes the risk-bearing reported LHDs categorized by general cause.

Table 4-2. Risk-bearing LHD Reports by Cause – 2017

LHD Category Code	LHD Category Description	Number of LHD	Duration at Uncleared FL (mins)	Number of Uncleared FLs Crossed
A	Flight crew failing to climb / descend the aircraft as cleared	2	7	0
B	Flight crew climbing /descending without ATC clearance	2	35	0
D	ATC system loop error; (e.g., ATC issues incorrect clearance or flight crew misunderstands clearance message)	3	120	0
E	Coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility as a result of human factors issues (e.g., late or non-existent coordination, incorrect time estimate/actual, flight level)	10	25	2
F	Coordination errors in the ATC-to-ATC transfer of control responsibility as a result of equipment outage or technical issues	0	0	0
G	Aircraft contingency event leading to sudden inability to maintain assigned flight level (e.g., pressurization failure, engine failure)	0	0	0
H	Airborne equipment failure leading to unintentional or undetected change of flight level (e.g., altimetry errors)	0	0	0
I	Turbulence or other weather related causes	1	15	0
J	TCAS resolution advisory; flight crew correctly following the resolution advisory	1	0	0
	TOTAL	**19**	**202**	**2**

4.3. A larger duration spent at the incorrect/uncleared flight level (FL) associated with reported LHDs is observed in 2017 compared to last year. There were 202 minutes spent at the incorrect/uncleared FL in 2017 compared to 139 minutes spent at incorrect

FL in 2016. The 2017 scrutiny review of the reported LHDs included reports of events occurring within Miami Oceanic and San Juan airspace in addition to the reported events occurring within New York West airspace.

4.4. **Figure 4-1** shows the comparison in number of risk-bearing LHD reports observed in 2017 with the 2016 results by LHD category. The vertical axis shows the observed counts within each LHD category. There were fewer risk-bearing LHDs in 2017 compared to 2016 data, 19 risk-bearing LHD reports in 2017 compared to 40 risk-bearing LHD reports in 2016. The categories in which the number of risk-bearing reports had observed decreases were in the pilot climb/descend not according to clearance (category A), pilot climb/descend without clearance (category B), ATC loop error (category D), and turbulence (category I). This result may be due to the effect of remedial actions undertaken as the result of the 2016 reported errors.

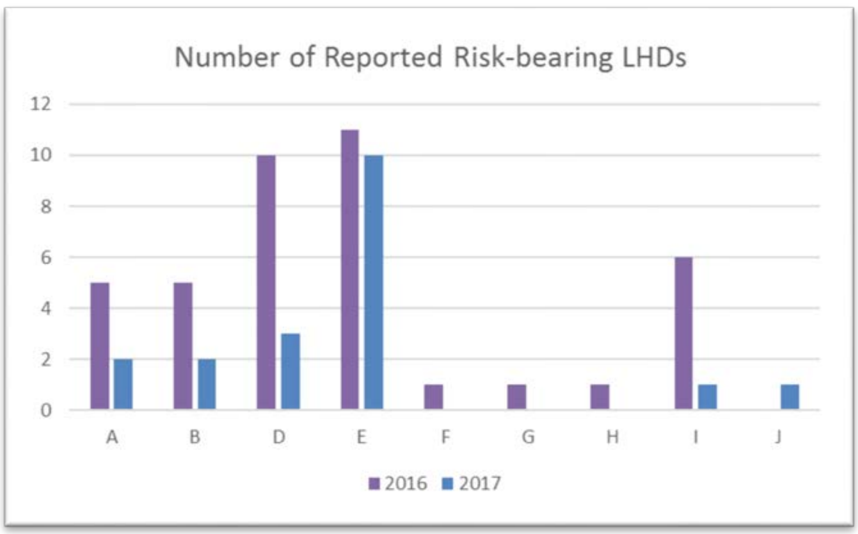

Figure 4-1. Number of reported risk-bearing LHDs by category code, 2017 vs 2016

4.5. **Figure 4-2** shows the comparison of the associated duration for reported risk-bearing LHDs in 2017 with the 2016 results by LHD category. The vertical axis shows the sum of the reported durations within each LHD category. There was significantly more time associated with reported LHDs involving ATC loop errors (category D) in 2017 compared to 2016. However, there was significantly less time associated with reported ATC-to-ATC transition errors (category E) in 2017 compared to 2016.

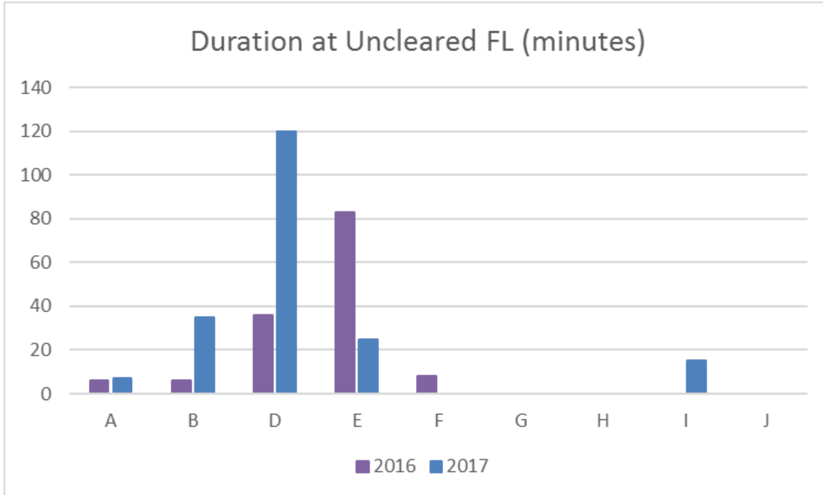

Figure 4-2. Duration at uncleared/incorrect FL (minutes) by LHD category, 2017 vs 2016

4.6. The risk-bearing LHDs classified as ATC loop error category (category D) contributed more than half of the duration spent at uncleared/incorrect FLs in 2017. There were three risk-bearing events in this category accounting for 120 minutes spent at the incorrect/uncleared FL. These three events were the result of an incorrect route amendment computer entry made by the transferring ATC facility, which caused the profiled route for the aircraft to reverse course and double back on itself. All of the aircraft involved were communicating with ATC via HF radio only and were not FANS 1/A equipped. As a result, data link communications and ADS-C periodic reports between compulsory reporting points were not available for these flights, which lengthened the time it took ATC to discover the route discrepancies. In each event, the error was identified when the aircraft did not report over an expected compulsory reporting point. The estimated time the aircraft operated within oceanic airspace without ATC protection was 40 minutes in each case.

4.7. The source of the three category D events was an error made in the flight data input/output (FDIO) amendment. The main corrective action taken has been to provide FDIO retraining to the ATC unit involved. These events took place in January, February and August 2017. During the scrutiny review, operational experts noted that it had been more than 12 months since the last of these events occurred without another incident which was taken as an indication of corrective-action success. Another mitigation planned is a change to the ATOP automation system that will alert an FAA controller when an aircraft route appears to double back on itself.

4.8. There are four risk-bearing LHD events that involve pilots climbing/descending without clearance or failing to climb/descend as cleared. The duration spent at uncleared/incorrect FL for these events, classified as category A and B, account for 21 percent of the total duration from all the risk-bearing LHDs in 2017. The scrutiny group experts did not identify any systematic causes for these four events and was therefore unable to recommend any appropriate remedial actions to mitigate the future occurrence of these types of events.

4.9. There are ten category E events, which involve coordination errors in the ATC-unit-to-ATC-unit transfer of control responsibility. Although more than half of all the risk-bearing LHDs are classified as category E, the sum of the time spent at uncleared / incorrect FL for these events account for only 25 minutes or 12 percent of the total duration from all the risk-bearing LHDs in 2017. The reason for the relatively short durations associated with these events is the available radar surveillance and ADS-C reporting for some of these events which provide ATC with an opportunity to identify the error shortly after entry or even prior to entry into the airspace which is the subject of this report.

4.10. 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 airspace. **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 – 2017

Airspace	Number of LHD	Duration at uncleared FL (min)	Number of uncleared FLs crossed
Miami Oceanic and San Juan	4	5	2
New York West	15	197	0

4.11. **Figure 4-3** shows the approximate locations of the risk-bearing LHDs in 2017. All three of the category D events began at the same boundary point in the airspace. All of the category E events occur on an ATC boundary.

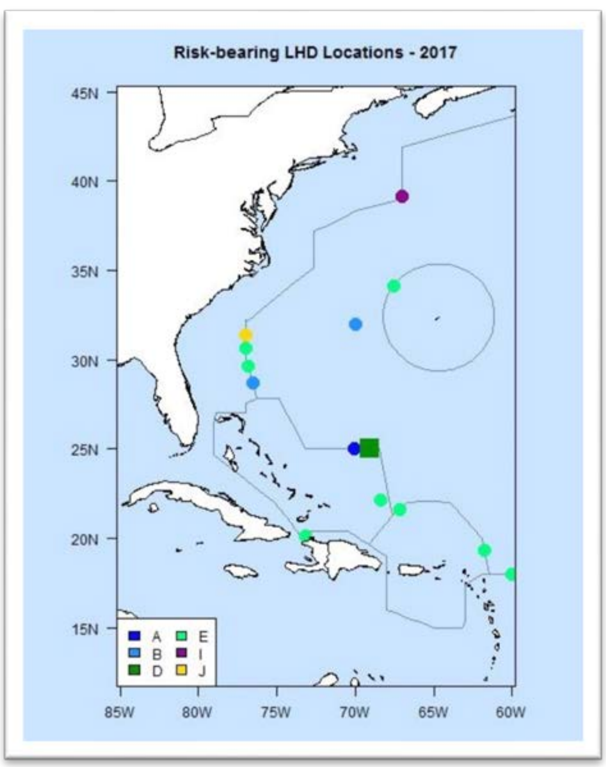

Figure 4-3. Approximate Location of the Risk-bearing LHDs - 2017

4.12. The NAARMO organized scrutiny-group teleconferences between the various ATC facilities to review the events reported during 2017. 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. In the future, in order to solicit as much information as possible, 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 2017 traffic data, the NAARMO estimates approximately 493,575 annual flying hours for 2017 in Miami Oceanic, New York West, and San Juan airspace where the RVSM is applied. 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. Thus, an interpretation of the TLS value associated with RVSM in Miami Oceanic, New York West, and San Juan airspace where the RVSM is applied will be safe if the expected number of collisions does not exceed an average of 1 every 405 years, where the number of flying hours in a year are roughly 0.5 million.

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:

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

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 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 2017 traffic data by flying hours. The two traffic data sources are maintained in these data; 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 20 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 30 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 26 percent of all the flying hours observed in the traffic data.

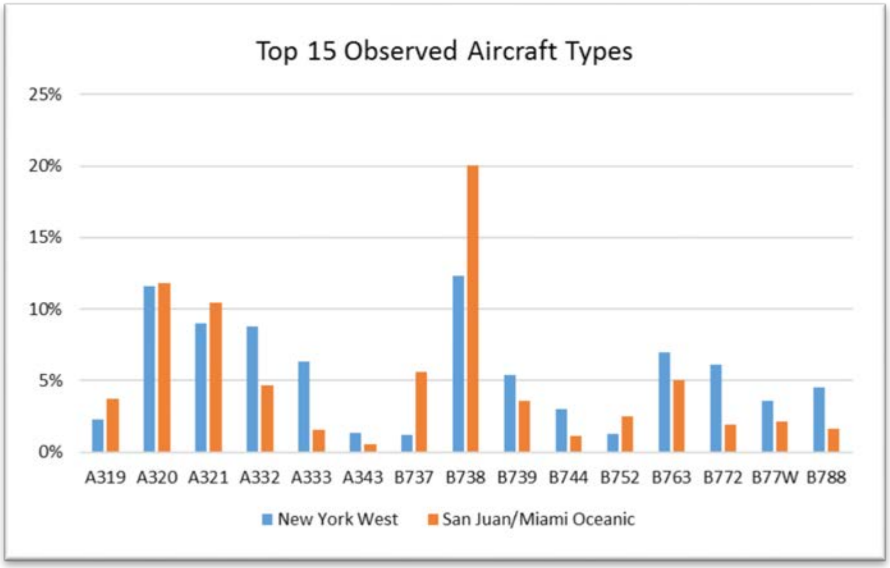

Figure 5-1. Observed Aircraft Types in Terms of Flying Hours in Miami Oceanic/San Juan and New York West Airspace

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 2017 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	0.0235 *(143 ft)*	0.0216 *(131 ft)*	0.0071 *(43 ft)*
New York West	0.0278 *(168 ft)*	0.0259 *(157 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 2017 is approximately the same as the value estimated in 2016. The opposite direction vertical occupancy value for New York West airspace for 2017 is 30 percent lower than the value estimated in 2016. This result was expected because there was an additional north-south route established in August 2017, route L576. This route reduces same-route opposite-direction traffic by dispersing the traffic among more routes.

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	0.0676	0.0569
New York West	0.0482	0.0742

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 2017 data was 1,992. This value, prorated from the 31-sample days for the calendar year 2017, is 23,454 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 x 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 Uncleared 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 2017 contain 202 minutes of flying time spent at uncleared flight level.

5.11.2 Table 4-3 provides the duration at uncleared / incorrect flight level for both areas. The proportion of flying time spent at uncleared flight level is estimated for each area using the values in Table 4-3 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 251,575 hours. The estimated annual flying hours for Miami Oceanic and San Juan airspace obtained from the TFMS data are 242,471 hours. The resulting ratios of time spent at uncleared flight level are 1.31×10^{-7} and 3.44×10^{-7} 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.	0.0235 NM and 0.0278 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_y	Average aircraft wingspan.	0.0216 NM and 0.0259 NM	Estimated from Miami Oceanic/San Juan and New York West traffic data
λ_z	Average aircraft height with undercarriage retracted.	0.0071 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.	0.068 and 0.048	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.	0.057 and 0.074	Estimated from Miami Oceanic/San Juan and New York West traffic data

Term	Definition	Estimate	Source
$\overline{\lvert \Delta V \rvert}$	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	251,104	Estimated from FAA ATOP DR&A for New York West airspace
F(MS)	Estimated flying hours within Miami Oceanic and San Juan FIRs	242,471	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 2017 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. 2017 Vertical Risk Estimates for Miami Oceanic, New York West and San Juan Airspace (x 10^{-9} fatal accidents per flight hour (fapfh))

Airspace	Technical	Operational	Overall
New York West	0.03	85.35	85.38
Miami Oceanic and San Juan	0.02	2.09	2.11
Total	**0.05**	**87.44**	**87.49**

6.2. The estimated technical risk in the RVSM airspace is 0.05 x 10^{-9} fatal accidents per flight hour (fapfh). This estimate is significantly below 2.5 x 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 85.38 x 10^{-9} fapfh. The sum of this value and the technical risk estimate for airspace is 87.49 x 10^{-9} fapfh, or seventeen times greater than the overall safety goal of 5.0 x 10^{-9} fapfh. More than half of the calculated vertical risk is attributed to the three category D events accounting for 120 minutes of time spent without ATC protection. These events took place in January, February and August 2017. During the scrutiny review, operational experts noted that there had been more than 12 months since the last of these events occurred without another incident which was taken to be an indication of corrective-action success. The main corrective action taken as a result of these events was to provide FDIO retraining to the ATC unit involved. Another planned mitigation is a change to the ATOP automation system that will alert ATC when an aircraft route appears to double back on itself.

6.4. The NAARMO will organize the scrutiny review for 2018 events to begin during the fourth quarter of 2018. The earlier review planning should allow for inclusion of operator responses and more information from ANSPs for the reported events.

6.5. The estimated vertical risk estimate for 2017, shown in **Table 6-1**, is lower than the estimate for 2016. The overall vertical risk estimate in 2016 was 219.2 x 10^{-9} fapfh. The decrease in the vertical risk estimate is attributed to the inclusion of more airspace in the analyses resulting in a larger number of annual flying hours used in the risk calculation. In addition, the lower opposite-direction vertical occupancy value for New York West airspace produces a lower risk value than reported in previous years. The vertical collision risk model is sensitive to the opposite-direction occupancy value.

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