International Civil Aviation Organization

The Twenty-First Meeting of the Regional Airspace Safety Monitoring Advisory Group (RASMAG/21)

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Agenda Item 3: Reports from Asia/Pacific RMAs and EMAs

ESTIMATION OF VERTICAL OVERLAP PROBABILITY FOR BOB AND WPAC/SCS REGIONS

(Presented by the Monitoring Agency for Asia Region)

SUMMARY

This paper presents the result of the MAAR's estimate of probability of vertical overlap ($P_z(1000)$) using recent vertical error data from Bay of Bengal (BOB) and Western Pacific/South China Sea (WPAC/SCS). A conservative value of $P_z(1000)$ obtained from this calculation is 3.076 x 10^{-10}, which is smaller than the currently used value of 1.70 x 10^{-8}. The result suggests that the value currently being used in MAAR's risk estimation may be overly conservative.

1. INTRODUCTION

1.1 Probability of vertical overlap for two aircraft flying at 1000 feet separation ($P_z(1000)$) is an important parameter used in airspace risk calculation. The Monitoring Agency for Asia Region (MAAR) has been using a $P_z(1000)$ value of 1.7 x 10^{-8}. As stated in ICAO Doc 9574, the $P_z(1000)$ value of 1.70 x 10^{-8} is a conservative value used to define RVSM operation requirements, e.g. aircraft height-keeping and operating procedures. This value was estimated in 1998. In order to investigate if the conservative value of $P_z(1000)$ calculated in 1998 is still an appropriate value to be used for the regions' risk estimation, the MAAR used the same model and methodology and more recent data to re-estimate $P_z(1000)$. This paper presents a preliminary result of the calculation.

2. DISCUSSION

Probability of Vertical Overlap (P_z) Model

2.1 The mathematical model used to represent P_z is the same model as in "Fitting Aircraft Height-keeping Data to a Family of Symmetric Statistical Distribution Models and Estimating $P_z(1000)$," a paper by the Federal Aviation Authority (FAA) Technical Center. The goal of this model is to calculate a conservative estimate of $P_z(1000)$. The model and methodology are outlined below.

2.2 **Probability Distribution of Total Vertical Error (TVE):** To calculate $P_z(1000)$, a probability distribution of TVE must be obtained. TVE can be broken down into two components:

- Altitude keeping error, which is composed of assigned altitude deviation (AAD) and technical large height deviation (LHD); and
- Altimetry system error (ASE) for each MMR group, which is modelled as sum of two random variables. The first variable is ASE mean and the second variable is ASE within airframe difference, representing fluctuation of each ASE sample from the ASE mean of the airframe. After the distribution of ASE for each MMR group is

determined, ASE distributions are mixed according to proportion of time aircraft in the group fly in RVSM airspace.

2.3 TVE distribution is obtained by convolving altitude keeping error distribution and ASE distribution. The TVE components and probabilistic distribution used to represent them are depicted in **Figure 1**.

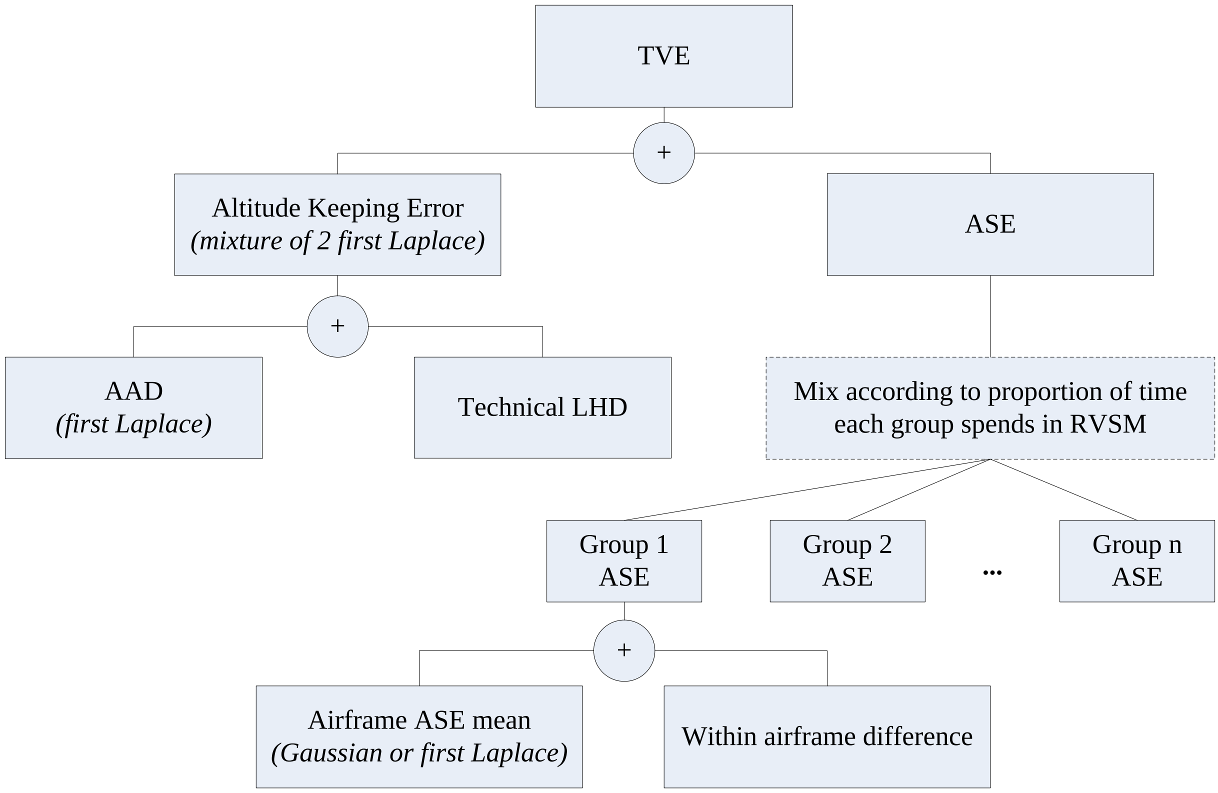

Figure 1: TVE Components

2.4 **Probability of Vertical Overlap (P_z):** Two aircraft are considered overlap if the separation between them is less than aircraft height. To obtain P_z, TVE distribution is self-convolved and integrated over twice average aircraft height.

2.5 The FAA Technical Center developed Fortran scripts to estimate P_z (1000) according to the model presented above; however, the program is no longer compatible with modern operating systems. Therefore, the MAAR developed a program employing the same methodology but using Python instead.

Data Used in P_z (1000) estimation

2.6 The data samples used in the estimation are the following:

- 1 month of AAD data from MAAR's ADS-B Height Monitoring System (AHMS) over the Bangkok FIR during March 2015.
- 2 years of technical LHD data from 2014-2015 reports submitted by BOB and WPAC/SCS States.
- 16 months of ASE data from MAAR's AHMS from March 2014 to June 2015

All data was weighted and scaled to account for different duration of data collection periods.

2.7 Please note that 55% of aircraft flying in Bangkok FIR's airspace is equipped with ADS-B out. Proportion of time each Minimum Monitoring Requirement Group (MMR) group aircraft spent in RVSM is calculated from 2014 Traffic Sample Data (TSD) submitted by BOB and SCS states.

2.8 Since the value of $P_z(1000)$ is sensitive to the aircraft height being chosen for the calculation, the MAAR calculated values of $P_z(1000)$ for different values of aircraft heights, as shown in the table below:

Average Aircraft Height(ft)	**$P_z(1000)$**	**Remark**
28	0.6927×10^{-10}	
50	1.443×10^{-10}	Average aircraft height flying in BOB and SCS RVSM
60	1.965×10^{-10}	B747 aircraft height
79	3.076×10^{-10}	A380 aircraft height

2.9 According to the calculation, the conservative value of $P_z(1000)$ for SCS and BOB region is 3.076×10^{-10}, which is two orders of magnitude smaller than 1.70×10^{-8}, the value currently used. This suggests that the value currently being used in MAAR's risk estimation may be overly conservative. However, the MAAR suspects that technical LHDs in SCS and BOB, which have a big impact on the estimate of $P_z(1000)$ in this study, may have been under-reported. As a result, $P_z(1000)$ presented in this study may have been underestimated.

2.10 In addition, AAD and ASE data used in this calculation was obtained from MAAR's AHMS, which only covers aircraft equipped with ADS-B out flying in the Bangkok FIR's RVSM airspace. The ASE sample, therefore, may not accurately represent height keeping performance of all aircraft flying in BOB and SCS's RVSM airspace.

Further Study

2.11 Since the technical LHDs used in this calculation may be under-estimated, the MAAR plans to include technical LHD reports from other regions with more data.

2.12 It is not clear whether sampling only from ADS-B-out aircraft has any significant impact on the evaluation of ASE. Therefore, the MAAR plans to compare ASE distribution obtained in this analysis to ASE distribution obtained from other RMAs.

2.13 $P_z(0)$, defined as probability of overlap between two aircraft flying at the same flight level, is another relevant parameter used in operational risk calculation. The MAAR also uses the same model and data to calculate $P_z(0)$. The calculated $P_z(0)$ is 0.5264 if B747's height is used and 0.6486 if A380's height is used, which do not differ much from the currently used value of 0.538. This confirms that the value of $P_z(0)$ currently used is still reasonable. However, further study of this parameter's estimation may be required since it contributes most to the operational risk, and therefore, the total collision risk.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper; and

b) discuss any relevant matters as appropriate.

REFERENCES

Federal Aviation Authority Technology Center. “Fitting Aircraft Height-keeping Data to a Family of Symmetric Statistical Distribution Models and Estimating Pz(1000)”.

ICAO. Doc 9574 “Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum Between FL 290 and FL 410 Inclusive”, 2nd Edition, 2002.

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