International Civil Aviation Organization

Middle East Regional Monitoring Agency Board

Eighteenth Meeting (MIDRMA Board/18)
(Doha, Qatar 19 – 20 September 2022)

Agenda Item 4: RVSM Monitoring and related Technical Issues

ADS-B HEIGHT MONITORING SYSTEM (AHMS)

(Presented by MIDRMA)

SUMMARY

ADS-B Height Monitoring System (AHMS) use ADS-B receivers to obtain geometric height data from ADS-B equipped aircraft. The use of this method requires the aircraft to be ADS-B equipped and for the aircraft to fly in a region where ADS-B monitoring is performed.

Action by the meeting is at paragraph 3.

REFERENCES

- ICAO Annex 6 Part 1
- ICAO Doc 9574
- ICAO Doc 9937

1. INTRODUCTION

1.1 With the endorsement of ADSB Height Monitoring methodology by the ICAO Separation and Airspace Safety Panel (SASP), ADS-B data can be used for calculating the Altimetry System Error (ASE) which is a measure of the height-keeping performance of an aircraft. It is an ICAO requirement that aircraft operating in RVSM airspace must undergo periodic monitoring on height-keeping performance.

1.2 The ICAO Separation and Airspace Safety Panel (SASP) first considered the use of geometric height data from ADS-B systems in 2001. While further consideration was given to this issue by SASP in the intervening years, activity was started in earnest following work after significant progress was made with test flights conducted by the United States FAA in 2008 and early 2009 which demonstrated that aircraft geometric height data obtained from ADS-B is sufficient for estimating aircraft Altimetry System Error (ASE).

2. DISCUSSION

2.1 Altimetry System Error (ASE) is a measure of the height-keeping performance of an aircraft. In airspace where RVSM applied, the importance of accurate aircraft height-keeping performance is magnified. Aircraft use a barometric altimeter to determine height and follow common pressure levels in

RVSM airspace. The errors in the aircraft altimetry sensing systems are not apparent during routine operations as the altimeter displays to the aircrew and Air Traffic Control a flight level which contains the ASE. Due to the existence of aircraft ASE, the observed flight level by the pilot and ATC is different than the actual height of the aircraft.

2.2 The altimetry system utilizes parts that can wear over time (e.g. the pitot-static probe); can be damaged (e.g. skin flexing/deformation during operations); and can be effected by modifications made to the airframe (e.g. the application of paint or mounting of accessories in the vicinity of the static pressure port). These activities can affect the aircraft's altimetry system in a negative way, producing a significant error in true height. Other factors from normal operations of high-speed flight such as aerodynamic loading and exposure to ranges of temperature, moisture and contaminants, are also capable of producing significant variation in the sensed pressure of the altimetry system. Since the ASE is not detectible in routine operations; specialized measurement equipment is necessary to independently measure the errors. If an aircraft is unable to maintain its desired altitude relative to others, it poses a greater threat to the other aircraft in the system. Therefore, the ICAO developed standards that individual aircraft and aircraft groups must meet in order to operate in RVSM airspace.

2.3 In addition to the methods available for RVSM height monitoring and on the basis of the research completed and the outcomes provided over a number of years, both the SASP and RMACG have endorsed the use of ADS-B as another method of height monitoring.

2.4 Using ADS-B for height-keeping performance monitoring requires that the aircraft use ADS-B Out and operate within the coverage area of an ADS-B ground station receiver. In comparison to the other existing ground-based monitoring systems, such as the Height Monitoring Units (HMU) and Aircraft Geometric Height Monitoring Element (AGHME) that have a coverage area of 40-NM, the defined coverage area of the monitoring system utilizing ADS-B data is much larger. The coverage area for one ADS-B ground station is roughly 200-NM. In this case, the ADS-B ground station potentially serves two purposes; providing information needed for air traffic control and aircraft height-keeping performance monitoring.

2.4.1 What does ADS-B OUT and IN mean?

a) "ADS-B OUT" is the transmission of ADS-B information out from an aircraft to other aircraft or to the ground. In some FIRs ADS-B OUT has been made mandatory for IFR aircraft over an extended transition period. Compliance dates for ADS-B OUT depend on whether the aircraft flies in upper or lower airspace; and
b) "ADS-B IN" is the on-board reception of ADS-B OUT transmissions to allow a Cockpit Display of nearby aircraft to the pilot of the ADS-B IN equipped aircraft. No idea if there are plans to mandate this type of ADS-B.

2.5 ADS-B monitoring is undertaken by processing of large data sets of ADS-B messages captured in the coverage area of ADS-B Network. The data is processed to enable the calculation of Altimetry System Errors (ASEs) for each ADS-B message obtained from a specific aircraft or group of aircraft. A final assessed ASE value is then calculated for each observed aircraft.

2.6 Two big advantages of sourcing aircraft geometric height data from ADS-B transmissions are: data collection is passive and does not require any special arrangement with the aircraft operator provided aircraft follow the monitoring requirements or interaction with the flight crew and; the geographical region over which flights can be captured is limited only by the ground station network. The first means that ASE measurements can be performed as many times as thought necessary with only a processing-time penalty. The geographical range could easily be State-wide or wider since a ground station is a relatively cheap and simple unit which can be co-sited with an existing installation (eg VHF antenna). Usually all ADS-B transmissions received at a ground station from ADS-B equipped aircraft are stored. It is therefore feasible to use this data to monitor aircraft height-keeping performance at the fleet level and to provide a thorough ASE history profile for individual airframes.

2.7 There is ample information available in an aircraft's detailed ADS-B report history to detect and confirm aberrant or non-compliant Altimetry System Error (ASE) behavior. Systems were established to process a State-wide volume of ADS-B data in order to regularly height monitor all ADS-B equipped aircraft in the State's airspace. The volume of ADS-B data available in States is so large which required certain training to organize the data to facilitate searches and retrievals.

2.8 The reported geometric height derived from the ADS-B GPS is either height above the WGS-84 ellipsoid (HAE) or height above mean sea level (HAMSL). Either is valid since they are both approximations to an ideal Earth surface. However, for the precision required to measure ASE it is essential to determine which height datum an aircraft GPS uses, HAE or HAMSL.

2.9 The ADS-B Height Monitoring System (AHMS) uses the calculation of ASE involves several sources of error including a poor local fit to meteorological data, ADS-B height discretization (to every 25 ft) and geoid interpolation. Daily ASE measurements for an airframe vary quite a lot due mainly to 'meteorological error'. However, as more data is collected the mean ASE value becomes a robust estimate of ASE. ASE is first represented as an average over all point-time values on a given day. The estimated ASE for an airframe is the mean of these daily averages except where significant trends in the data occur. If a trend in the daily ASE data is observed then linear regression methods are used to estimate the trend slope (in feet per year) and the most appropriate ASE value.

2.10 ADS-B allows equipped aircraft to automatically broadcast their position, velocity, and other information with each other and with air traffic controllers. ADS-B equipped aircraft use an on-board Global Positioning System (GPS) receiver to determine their position, this time-stamped information is then broadcast along with other aircraft information to all ADS-B capable aircraft and to ADS-B ground or satellite communications receivers. These receivers then forward the information to Air Traffic Control (ATC) centers. The ADS-B reports includes aircraft geometric height, which is a key component in the ASE estimation process.

2.11 The geometric height obtained from the EGMU is differentially corrected prior to the ASE calculation. This means that much of the position errors are removed from the GPS-derived geometric height with further processing. The GPS-derived geometric height contained in the ADS-B message is not differentially corrected. It is not possible to post-process these geometric heights because the information needed to correct the errors is not included in the ADS-B messages. Some conditions have changed since the initial determination of suitability of uncorrected GPS pseudo ranges. First, aircraft grade GPS receivers have improved markedly and being capable of tracking more satellites simultaneously. Additionally, the Selective Availability (SA) feature of the GPS system has been completely disabled to the point where non-precision approaches can be attempted with its course guidance. These changes in conditions mean that better accuracy can be expected in the geometric height determined from the modern receivers.

2.12 The ASE software was developed which requires aircraft geometric height data, actual flight level (altimetry reading) data, intended flight level for the flight segment and an independent source for meteorological data. Prior to producing estimates of aircraft ASE, the ADS-B data were reformatted and preprocessed to remove unnecessary data fields. The ASE processing begins with the identification of unique straight and level flight segments for each flight observed in the data. A straight and level flight segment is defined by a constant flight level (altimetry reading – Mode S) and without turns.

2.12.1 Each straight and level flight segment is considered to be an independent observation. It is possible for the same flight/aircraft operation to have more than one straight and level flight segment in the data as aircraft routinely climb or descend to different flight levels and make turns while in cruise. The ADS-B derived aircraft geometric heights which are quantized to 25 ft. are smoothed to reduce any random noise and remove some of the effect of the quantization. The smoothing method used is a nonparametric regression based on the maximum likelihood estimation of a signal-in-noise mod.

2.13 Update of ADSB Coverage in the Middle East Region

2.13.1 As far as the MIDRMA aware, ADSB is available for surveillance in the following MIDRMA Member States airspace:

1- Kuwait.
2- Qatar.
3- Oman.
4- Sudan.
5- UAE.
6- Bahrain (Under installation).
7- KSA (Under Installation).

- Jordan – The System is not used for surveillance.

2.13.2 The MIDRMA conducted a statistical study of all RVSM approved aircraft registered in the ICAO Middle East region and continued to update this study to confirm the status of the ADSB equipage of all MID RVSM approved.

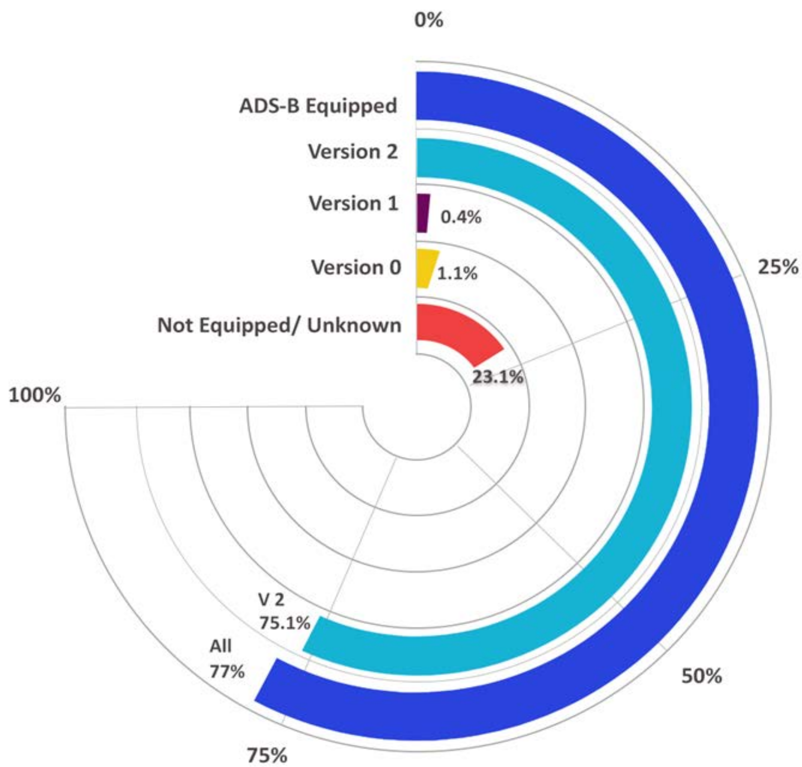
2.13.3 The response of all MIDRMA Member States to obtain the necessary information concerning the equipage of ADSB out of their RVSM approved aircraft was acceptable, with the exception of Syria, Libya and Yemen focal points for Airworthiness issues which never responded to the MIDRMA's repeated correspondences which resulted excluding them from the study.

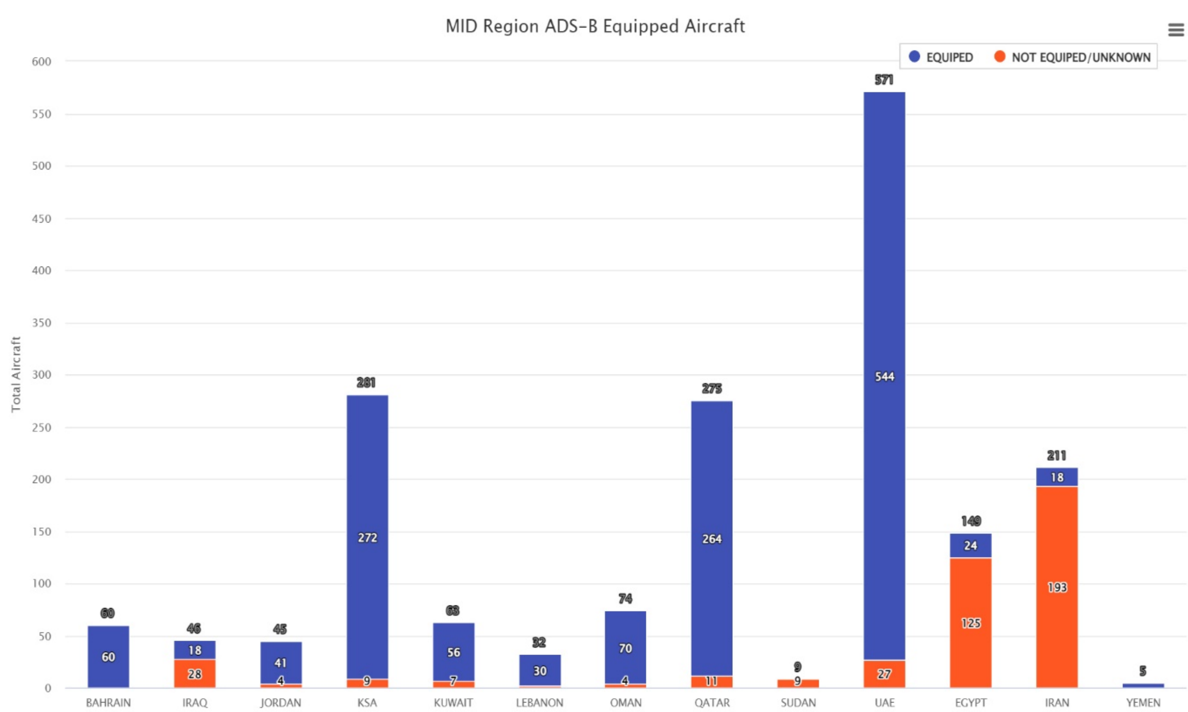
2.13.4 The results of the study that was conducted for the updated MID RVSM approved aircraft database for 13 member states (depicted in the table below)

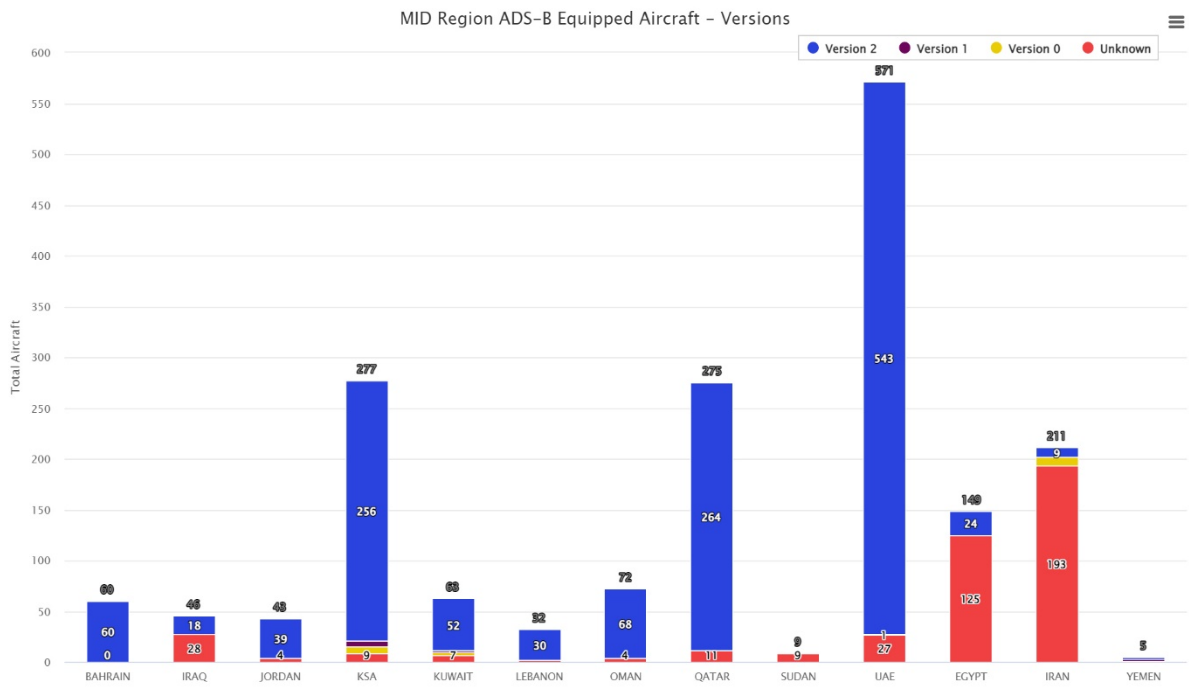
2.13.5 The study was targeting the equipage of ADSB Out in the MID RVSM approved aircraft in order to know the benefit of conducting RVSM height monitoring by using the ADSB Out archived data and to know what versions are installed in these aircraft which they should be as follows:

a. DO-260 (Version 0)
b. DO-260A (Version 1)
c. DO-260B (Version 2)
d. DO-260C (Version 3), approved by December 2020

ABS-B	Total	Equipped	Not Equipped/ Unknown	V2	V1	V0
BAHRAIN	**60**	**60**	0	**60**	0	0
IRAQ	**46**	**18**	28	**18**	0	0
JORDAN	**45**	**41**	4	**39**	0	0
KSA	**281**	**272**	9	**256**	6	6
KUWAIT	**63**	**56**	7	**52**	1	3
LEBANON	**32**	**30**	2	**30**	0	0
OMAN	**74**	**70**	4	**68**	0	0
QATAR	**275**	**264**	11	**264**	0	0
SUDAN	**9**	**0**	9	**0**	0	0
UAE	**571**	**544**	27	**543**	0	1
Egypt	**149**	**24**	125	**24**	0	0
Iran	**211**	**18**	193	**9**	0	9
Yemen	**6**	**5**	**1**	**2**	**2**	**1**
TOTAL	**1822**	**1402**	**420**	**1365**	**9**	**20**
%		**77.3**	**23.1**	**75.2 (97.4% of the Total Equipped ACFT)**	**0.5**	**1.2**
Syria	**No Data Submitted**					
Libya	**No Data Submitted**					


0%
ADS-B Equipped
Version 2
Version 1
0.4%
Version 0
1.1%
Not Equipped/ Unknown
23.1%
25%
100%
V 2
75.1%
All
77%
50%
75%


MID Region ADS-B Equipped Aircraft
EQUIPED
NOT EQUIPED/UNKNOWN
Total Aircraft
BAHRAIN
IRAQ
JORDAN
KSA
KUWAIT
LEBANON
OMAN
QATAR
SUDAN
UAE
EGYPT
IRAN
YEMEN



2.13.6 The results identified **77.3%** (from 13 Member States) of the aircraft can benefit from ADSB RVSM height monitoring taking into consideration that we are still missing the ADSB information of **45** aircraft registered by Libya and Syria.

2.13.7 The results of the statistical study are very encouraging and reflected good percentage of the RVSM approved aircraft equipped with ADSB-Out in addition these aircraft scored a very high percentage as well that equipped with ADSB-Out **Version 2** of **97.4%**, while very small percentage of Version 0 and 1. In the two graphs above reflecting the aircraft equipage rate is the percentage of ADSB Version 2 equipped aircraft with respect to the total aircraft fleet.

2.14 MIDRMA needs the cooperation of all member states to start implementing this type of RVSM height monitoring, especially member states already installed and using ADSB so that the MIDRMA team start training, performing data checks, extracting data from archive database, and train ADSB engineers responsible for providing and uploading the required data to the MIDRMA servers at agreed regular intervals.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) review and discuss the contents of this working paper;

b) encourage States to share their archived ADS-B data with the MIDRMA for RVSM height monitoring; and

c) decide how to proceed with the implementation of AHMS within the Middle East Region.

- END -