Common EUR RMA and RMA EURASIA Strategy for Data Sources and Height Monitoring Systems 2020-2030.

Abstract:

This paper proposes a strategic development path for the RMAs reporting to the ICAO EANPG over the time frame 2020 – 2030.

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1 Introduction

The basic driver behind the RMAs, stems from ICAO Annex 11 Section 3.3.5.1 This states:

> "For all airspace where a reduced vertical separation minimum of 300 m (1 000 ft) is applied between FL 290 and FL 410 inclusive, a programme shall be instituted, on a regional basis, for monitoring the height-keeping performance of aircraft operating at these levels, in order to ensure that the continued application of this vertical separation minimum meets the safety objectives. The scope of regional monitoring programmes shall be adequate to conduct analyses of aircraft group performance and evaluate the stability of altimetry system error[1]."

It is almost 20 years since Eurocontrol and the Authorities of the Russian Federation both accepted the task placed upon them by ICAO EANPG and established the EUR RMA and the RMA EURASIA.

Whilst the basic driver, as detailed in ICAO Annex 11, remains unchanged, both the operational and technical environment have evolved significantly over the intervening years. A strategy is now required to describe how best to address the challenges and exploit the opportunities that the evolution has introduced and to prepare for the changes that are foreseen in the coming years.

The ICAO EANPG, and its associated working arrangements, has requested both RMAs to provide a common future height monitoring strategy with the specific instruction that the proposal shall include maintaining current levels of monitoring while any transition to alternative methodologies are investigated, planned and deployed for the period 2020-2030 (**Draft EASPG Conclusion 1/2 – Proposed Future RVSM Monitoring Infrastructure**

> That, in light of the latest technological advances on ADS-B based RVSM monitoring and approach of the end of the service time of the existing HMUs supporting the work of the EUR RMA:
>
> a) The EUR RMA and the RMA EURASIA are tasked to carry out an analysis of the tools and methods for the height monitoring and provide a strategy for the deployment of the monitoring infrastructure at COG/75 and RCOG/12;
>
> b) EUROCONTROL be invited to ensure there are no gaps in the continuous availability of the EUR RMA RVSM monitoring function while the appropriate studies of new monitoring tools and their deployment are completed, including sufficient aircraft equipage levels).

The structure of this paper is:

- A high-level description of the current RMA situation in East and West Europe and relates it to other active RMAs around the world.
- An assessment of factors that influence the long-term strategy of the RMAs.
- A description of objectives that any proposed strategy should achieve.
- An exploration of alternative technologies that may be able to support height assessments and their relative merits.
- A proposal for a common Strategy for the EUR RMA and the RMA EURASIA.
- An exploration of the benefits the Strategy could help achieve.

[1] The specific requirements of the monitoring programme are defined in Annex 6 and RVSM guidance material and include; verification of individual aircraft altimetry system performance, verification of generic aircraft Minimum Aircraft System Performance Specifications (MASPS), operator compliance with fleet monitoring targets and finally to provide technical performance data for annual airspace safety assessments.

2 Monitoring Requirements

To operate in designated RVSM airspace an aircraft is required maintain vertical navigation performance in accordance with Appendix 4 of ICAO Annex 6.

When introducing RVSM operations it was proven that the altimetry system error (ASE) value for individual aircraft types may not be stable and that it can vary significantly over time.

In recognition of this, and to ensure safety of operations, Annex 6 also places obligations upon the State Authority that has issued an RVSM approval to an operator.

The Regional Monitoring Agency Coordination Group has developed a recommended Minimum Monitoring Requirements (MMR) table which includes a variable monitoring target which is dependent on performance and sample size.

In accordance with ICAO Doc 9574 and ICAO Doc 9937, the Authority is required to establish means which ensures that a minimum of two aircraft of each aircraft Type Grouping of the operator, have their height-keeping performance monitored. In summary, this monitoring is to be performed in accordance with the MMR i.e. at least once every two years or within intervals of 1000 flight hours per aircraft, whichever period is longer. If an operator's aircraft Type Grouping consists of a single aircraft, then it shall be monitored within the period specified above.

Not all aircraft configurations/types can be assigned to a separate aircraft type group as their altimetry system is not typical. Therefore, characteristics of all such aircraft, that are not assigned to a Type Group, are required to be monitored every two years.

The MMR determines a monitoring burden for each operator depending on its operating aircraft Type Group and the number of aircraft they operate in each Type Group.

The lowest level of monitoring required by the MMR equates to the Annex 6 requirements and is reserved for aircraft types that have a large number of compliant monitoring results which are stable over time, from a representative sample size. For aircraft types that do not satisfy one or more of these criteria, there is a higher monitoring requirement of 60% of an operator's fleet. For aircraft types with no monitoring history, or that do not satisfy generic aircraft performance requirements, it is possible for the RMA to allocate a 100% monitoring requirement.

As reported in the 2018 annual RVSM Safety Monitoring Reports by the two RMAs (See EANPG60 RASGEUR07 WPs 22 and 23), the current monitoring infrastructure in the ICAO European Region provides the following results of compliance with ICAO monitoring requirements:

- in the Western part of European region 93% of operators are in compliance with the minimum monitoring requirements
- in the Eastern part of European region 64% of operators are compliance with the minimum monitoring requirements

Whilst effective, the MMR approach is not without its limitations. It is possible that, due to the nature of an operator's fleet and the routes taken by assigned aircraft, some aircraft may never be monitored. Other aircraft could be monitored only sporadically – with poorly performing avionics going undetected for a significant period of time. The strategy proposed in this paper would, through the use of ADS-B data, extend the volume of airspace monitored significantly and would thus enable far more aircraft to be monitored more frequently with no extra burden placed upon the aircraft operators.

The principle purpose of the monitoring programme is to provide the means to support aircraft operators to comply with their Minimum Monitoring Requirements (MMR) and to provide sufficient data to enable the RMA to monitor aircraft altimetry system performance in designated RVSM airspace.

3 Current Situation of the Regional Monitoring Agencies

3.1 EUR RMA Region

The height monitoring infrastructure in the Western region of Europe, as served by the EUR RMA comprises: three Height Monitoring Unit (HMU) systems (located at Nattenhieim, Geneva and Lintz)

These monitor all transponder equipped aircraft operating within their coverage area. (It is to be noted that the radius of operation is limited to a maximum of 45 NMiles).

Due largely to site rental costs the HMU systems are relatively expensive to maintain. Since the HMU infrastructure was installed other operators with microwave dishes mounted on the towers have left and the cost burden for retaining the infrastructure is progressively being borne solely by the EUR RMA.

The HMU systems are aging with obsolescent components which will require an investment of approximately €5M to develop/replace (to replace all 3 HMU).

As an alternative to such an investment, discussions with the System Design Authority of the HMU have recently taken place regarding the anticipated duration over which the existing HMUs could remain operational. If the existing failure rates of key components continues in the manner already experienced then the use of components previously purchased to address obsolescence concerns should ensure the systems remain operational until at least 2025.

3.2 RMA EURASIA Region

The height monitoring infrastructure in the Eastern region of Europe, as served by the RMA EURASIA, currently comprises an ADS-B Height Monitoring System (AHMS) which is located in the Moscow ACC. The AHMS uses signals broadcast from ADS-B equipped aircraft. This passive monitoring is supplemented through the use of EGMU equipment which is used for on-board monitoring.

The Russian Federation authorities have not yet published any mandates requiring aircraft of operators to be equipped with ED-102A / D0-260B ADS-B version transponders.

As many ADS-B equipped aircraft operating in Eastern European airspace are configured with earlier ADS-B configurations the ADS-B monitoring currently only provides for approximately 50% aircraft only that are ADS-B equipped and flying in the airspace of Moscow ACC.

The RMA EURASIA are in the process of deploying four new HMUs (according to the approved Plan of development of the technical infrastructure for the monitoring of height keeping aircraft performance) to supplement the AHMS and EGMU.

3.3 Relevant Precedents Set in the Operations of Other RMAs:

3.3.1 NAARMO

For some years the NAARMO have operated an established and widespread deployment of 6 Height Monitoring Systems across the North American region[2]. Within the NAARMO these units, which utilise multi-lateration principles, are known as Aircraft Geometric Height Measurement Elements (AGHME). In 2019, a limited number of additional AGHME receiver units continue to be deployed.

The FAA require that the majority of aircraft operating in its airspace are equipped with ADS-B avionics by 1st January 2020. To receive the ADS-B transmissions, the FAA have an installed an operating network of more than 600 ADS-B ground-stations covering the United States of America,

[2] See ICAO RMACG/11-IP/26 (Status of Aircraft Geometric Height Measurement Element (AGHME) Constellations in the North American Region) (May 2016)

the Gulf of Mexico and Alaska[3]. The data from the network of ATC quality ADS-B sensors is shared across the FAA and is available for use by the NAARMO.

Since 2015[4], the NAARMO have developed, and continue to refine, software that is capable of providing Altimetry System Errors for aircraft based upon their ADS-B (ED-102A / DO-260B) broadcasts.

Whilst it is technically possible to utilise the ADS-B transmissions from previous versions e.g. DO-260, the NAARMO have decided to simplify their assessments and use only those ADS-B broadcasts that are in accordance with the mandated requirement. NAARMO employ the principle that the 'Best Equipped are Best Served' i.e. Aircraft that are not appropriately ADS-B equipped will need to operate over an AGHME system in order to achieve their monitoring targets.

The NAARMO are using the ADS-B data to monitor, with a high rate of occurrence, the height keeping performance of individual aircraft. Through this means, they expect to be able to identify aircraft with emerging anomalous height keeping performance at an earlier stage than is currently possible. It is also hoped that assessing ADS-B data from aircraft operating across the country will prevent the situation in which some aircraft are never subject to ASE monitoring.

The NAARMO approach runs the ADS-B Height Monitoring System (AHMS) software in parallel with data from the AGHME infrastructure.

In using different technological methods to measure ASE, the AGHME and AHMS configurations complement each other by offering a means of cross-verification between the two different types of monitoring systems.

The fact that the combination of AHMS and AGHME provides full-scale monitoring for all aircraft in the USA airspace is allowing the FAA (NAARMO) to simplify the procedure of granting of RVSM approval for domestic aircraft.

The NAARMO are planning to operate a DTMS, with their existing AGHMEs operating in parallel to AHMS, until at least 2025[5].

3.3.2 NAT CMA

The NAT CMA have a single, older generation HMU located at Strumble. ICAO NAT, who fund the operation of the NAT CMA, have concluded that this is now reaching the end of its operational life and are preparing to phase the system out of operation in 2020[6]. Given the prevalence of ADS-B equipped aircraft operating across the North Atlantic NAT CMA are currently assessing how best to introduce an ADS-B based monitoring configuration.

Aircraft operating in the airspace monitored by NAT CMA are required to comply with ADS-B equipage mandates for the regions they will operate in e.g. ED-102A / DO-260B.

The ADS-B data will be sourced from ATC quality sensors (from ANSPs accredited to the NAT CMA and potentially also from Space Based ADS-B sensors).

[3] See ICAO RMACG/10-IP/10 (Distribution of Altimetry System Error Results from the US ADS-B Data) (May 2015)
[4] See ICAO RMACG/14-IP/24 (Technical Height Monitoring with ADS-B) (June 2019)
[5] See ICAO RMACG/14-WP/273 (The Use Of Automatic Dependent Surveillance – Broadcast Out (ADS-B OUT) In Support Of Reduced Vertical Separation Minimum (RVSM) Operations) (June 2019)
[6] See ICAO RMACG/14-IP/05 (North Atlantic Height Monitoring System Project Team Update) (June 2019)

4 Factors Influencing the Structure of the Strategy

4.1 Factors Arising from an Assessment of the RMA Infrastructure

A review of section 3 highlights numerous influencing factors for consideration when developing the strategy and lessons that could be learnt from other RMAs. These include:

a) The current monitoring infrastructure is unable to ensure full compliance with the ICAO Monitoring requirements in the RVSM airspace of both ICAO European Regions. (It is however noted that in the Western part of the region the level of compliance is very high and close to the target).
b) To ensure that the regional monitoring programmes are able to conduct analyses of aircraft type group performance, evaluate the stability of altimetry system error (as required in the Annex 11) and exclude the cases of aircraft that are rarely, if ever, monitored additional capabilities are required. An ADS-B monitoring (AHMS) covered the main part of ICAO European region airspace would address these issues.
c) The ICAO COG EASPG invited the RMAs to develop a strategy that ensures that there are no gaps in the continuous availability of RVSM monitoring function. That means that:
    1. The monitoring infrastructure in the Western part of European region should be kept, as minimum, on the current level until a new ADS-B based monitoring infrastructure is able to provide the same level of compliance.
    2. The monitoring infrastructure in the Eastern part of European region should be expanded and, as a minimum, its performance should approach the level of the Western part of European region.
d) In the airspace of the Russian Federation, and other States accredited to the RMA EURASIA, there are no mandates requiring operators to equip their aircraft with ADS-B ED-102A / DO-260B version transponders. The current infrastructure in the Eastern part of the European region should therefore be supplemented by the multi-lateration based method (HMUs).

4.2 Supplementary Influencing Factors

There are numerous drivers influencing the construction of a long-term strategy for the ICAO EUR regions RMAs.

1. Air traffic growth continues.
   As a result:
    - The long term monitoring of height keeping performance requirements remains necessary to ensure continued safety of operations in designated RVSM airspace.
    - To ensure continued safe operations in an increasingly traffic dense airspace it is recommended to seek ways extend the monitoring scope of the RMAs:
        - To increase the number of aircraft monitored.
        - To increase the frequency with which aircraft are monitored. (Previous monitoring experience has revealed that cases of a rapid degradation of an aircraft's height keeping performance can occur and that such issues require prompt detection and resolution).
        - Given the manner in which an aircraft operators fleet monitoring targets are expressed it is easy for aircraft never to be monitored (particularly for those elements of the fleet that are not operated on routes that pass within the constrained coverage volumes of the Height Monitoring Stations). If these aircraft could be monitored then general safety would be improved.

2. ADS-B Equipage Mandates become Effective and Equipage Rates Grow:
    - Correctly configured and certified ADS-B avionics on board an aircraft provides the RMA with an easily accessible, and potentially cheap, source of geometric height information.
    - It is to be noted that the European Commission have published Implementing Regulations (EU1207/2011 and subsequent adaptations) to mandate ADS-B equipage in a proportion of the fleet (those above defined weight and speed thresholds (i.e. greater than MTOM of 5700kg and/or a maximum cruising TAS greater than 250 Kts),
        - Current airspace requirement is for ADS-B carriage in Western Europe by for June 2020.
            - It should be noted however that current assessment indicates approximately 75% of the fleet operating in West Europe will be equipped by June 2020.
            - Managed exemptions will be permitted until near 100% of the mandated fleet is equipped by 2025.
            - The above date is To Be Confirmed by European Commission / EASA.
            - However, the Regulations published by the European Commission are <u>not</u> applicable to the entire fleet to be monitored by the RMAs. Either
                - The aircraft type is not covered within the scope of a mandate:
                    - State aircraft (Only transport type State aircraft are covered by EU1207/2011 and supplementary amendments).
                    - Aircraft below the weight and speed thresholds
                    - Aircraft exempted in accordance with a formal exemption scheme.
                - Non ADS-B based monitoring systems should be retained to ensure these aircraft can continue to be monitored.
            - For the purpose of developing this Strategy it is assumed that non-ADS-B equipped aircraft will need to be monitored until at least 2025 in Western Europe and throughout the term of the Strategy in Eastern Europe.
        - Other regions of the world have also introduced ADS-B mandates:
            - USA (DO-260B is mandatory for aircraft within designated airspace from January 2020).
            - Australia (DO-260 as a minimum)
            - China (currently some at DO-260 but evolving to DO-260B by 2022)
            - Russian Federation:
                - Even without a formal mandate requiring ADS-B equipage the number of ADS-B equipped aircraft operating in the airspace of the Russian Federation continues to grow.
                - This is occurring as the other mandates published elsewhere pertain to airspace rather than the aircraft's State of registration an increasing number of aircraft registered in States accredited to the RMA EURASIA are becoming ADS-B equipped.
                - Currently approximately 50% of the traffic monitored appear to be ADS-B equipped however aircraft conducting flights in

domestic airspace only, or to destinations where ADS-B is not mandated, will cause this level to plateau.

- Until it can be guaranteed that all aircraft operating in designated RVSM airspace are correctly ADS-B equipped there will be a need that both the EUR RMA and the RMA EURASIA continue to provide an HMU infrastructure to ensure that non-ADS-B equipped aircraft can be monitored.

3. Simplified Height Monitoring System Requirements if Using ED-102A / DO-260B type ADS-B Configurations

The performance requirements for Height Monitoring Systems are detailed in ICAO Doc 9937 where para 2.2.7 states:

> "As a means of ensuring both adequate accuracy in estimating TVE and transferability of monitoring results, an RMA must establish that any TVE estimation system which it administers has a mean measurement error close to zero and a standard deviation of measurement error not greater than 15 m (50 ft). Estimates of measurement errors associated with the HMU, AHMS and the GMS, which employs GMUs, should indicate that each system satisfies these requirements."
>
> Para 5.2.9 of ICAO Doc 9574 includes the following requirement: " ….. This accuracy should be such that the mean measurement error is 0 m (0 ft) and the standard deviation of measurement error does not exceed 15 m (50 ft)."

The ADS-B position declarations made from ED-102A / DO-260B configurations, (the version mandated in Western Europe, North America and China), are referenced to the Height Above Ellipsoid (HAE). In previous ADS-B versions, the configuration could broadcast values referred to either HAE or Height Above Mean-Sea Level (HAMSL). Without the knowledge of the reference level of certain aircraft, the Height Monitoring System cannot measure the ASE with required accuracy.

It is noted that the European mandate date is approaching and will be effective mid-2020. Deriving ASE measurement results of aircraft configured with previous ADS-B versions is unnecessarily complex and would introduce unwarranted development costs. Whilst this restriction currently reduces the number of aircraft that can be monitored by an ADS-B based monitoring system (For the West, the value is approximately 40% of those aircraft operating in Western Europe. For Eastern Europe the value is approximately 50% of those aircraft configured with ADS-B are equipped with ED-102A/DO-260B type configuration). The equipage curve of aircraft configured with ED-102A / DO-260B avionics is set to continue to grow with mandated requirements becoming effective in key regions across the world (USA, Europe and China).

4. Continued drive to reduce costs.

5. ICAO EANPG wish to retain the current level as a minimum level of performance. (See Conclusion from ICAO EANPG)

In summary, there is a need to develop a strategy that takes in to account the changing operational environment whilst cost-effectively exploiting the availability of suitably ADS-B equipped aircraft and also supporting the continued assessment of aircraft without ADS-B equipage.

5 Objectives of the Strategy:

The objectives behind the strategy proposed below are:

- To retain an ability to monitor non-ADS-B equipped aircraft though the use of dedicated HMU stations.
- To establish a verified / validated means to supplement the existing HMUs through an exploitation of an increasing availability of ADS-B data.
- To achieve cost savings when measured across a range of metrics e.g.
    - Reduced cost per aircraft monitored,
    - Reduced cost per km^3 of airspace volume monitored,
    - Reduced cost for aircraft operators whose aircraft comply with ADS-B mandates.
        - Extending the size of the region monitored could make it unnecessary for aircraft to conduct flights solely for the purpose of being monitored.
        - Aircraft would be monitored, more frequently and throughout a significantly greater volume of airspace – making it unnecessary for operators to conduct dedicated flights over an HMU. This would also simplify the way in which aircraft operators can achieve their monitoring targets.
- To address component obsolescence:
    - A further aspect, for consideration in the strategy, particularly concerning the Western region, is how best to manage an increasing obsolescence within the ageing EUR RMA HMU infrastructure.

The proposed strategy to achieve the above objectives also achieves additional safety related benefits by not only identifying anomalous avionic behaviour at an earlier stage but also by monitoring the height keeping performance of significantly more aircraft, with a more frequent rate of measurement, than the minimum fleet population currently required of aircraft operators. (Aircraft operators do not necessarily need to ensure that all aircraft in their fleet are assessed by an HMU. An operator may meet his monitoring targets through routine flights over the HMU infrastructure by certain aircraft in their fleet – but this can leave other aircraft in their fleet unmonitored. If there is no significant additional cost to capturing and assessing ADS-B data over an extended coverage volume more aircraft than just those within the vicinity of the HMUs could be assessed).

6 Alternatives and Technical Performance Requirements for Monitoring Tools:

The strategic choices are to maintain the existing HMU infrastructure, implement a new generation HMU, ADS-B monitoring systems or combination of these.

Technology:	**Advantages.**	**Disadvantages**
Maintain the Existing HMU Infrastructure	Monitors 100% transponder equipped RVSM approved aircraft in coverage area. Tried and trusted technique producing high quality ASE data. (A rough assessment of the cost per measurement, based upon the annual number of measurements made by the EUR RMA Height Monitoring Infrastructure cf. the annual running costs of the infrastructure, is approximately 0.6 Euro / aircraft measurement).	Low to medium operational costs (per aircraft measurement). Limited coverage area. (The EUR RMA HMUs will face obsolescence problems which will need to be addressed – especially if widespread ADS-B equipage is further delayed). Retention of the EURRMA HMU expected to be viable until 2025 – 2026.
Develop, Deploy and Validate a New HMU	Monitors 100% transponder equipped RVSM approved aircraft in coverage area. Tried and trusted technique producing high quality ASE data. (A rough assessment of the cost per measurement, based upon the annual number of measurements made by the EUR RMA Height Monitoring Infrastructure cf. the annual running costs of the infrastructure, is approximately 0.6 Euro / aircraft measurement).	High development / deployment cost, low to medium operational costs (per aircraft measurement). Limited coverage area. (The EUR RMA HMUs will face obsolescence problems which will need to be addressed – especially if widespread ADS-B equipage is further delayed).
ADS-B	Cheaper (Low deployment cost, low operational costs (per aircraft measurement). Provides a potential mechanism to monitor more aircraft and thereby identify ASE issues on aircraft not yet assessed and thereby improve safety. Provides a potential mechanism for a more rapid interface to detect and resolve ASE errors.	Can only monitor suitably equipped aircraft For some years there will be insufficient aircraft equipped with ADS-B to ensure that the current levels of monitoring can be met. Software needs to be developed (for EUR RMA)

	Provides potential means to analyse individual aircraft performance rather than a group analysis. This approach would also simplify the group monitoring aspects as the focus would be on individual aircraft rather than their performance within a group). (A formal estimate of cost per measurement has yet to be made but is expected to be significantly less than a Euro per measurement and covering a larger volume of airspace).	
Dual Technology (HMU and ADS-B) Monitoring System Configuration	All aircraft (ADS-B equipped or not). Supports transition and consistency of reports. Depending upon the costs involved with souring the ADS-B data the cost per measurement is not expected to differ significantly from the basic HMU costing. Even though there will only be a partial coverage between the HMU and ADS-B some performance cross verification would be achievable.	Initial development cost for the assessment software to be used by the EUR RMA. Slightly higher total annual cost (but as the coverage is across a greater volume of airspace with more aircraft monitored the individual assessment cost will be comparable to the HMU standalone configuration).
GMU	Allows aircraft that will not be operating in the region of the HMUs to be height monitored.	Expensive. Not a practical solution for multiple aircraft as the process is too complicated and the cost per measurement is approximately 5-10KEuro (depending upon factors such as when / where the measurement will take place)

Based on the above the following is the proposed strategy.

7 Proposed Strategy:

The proposed strategy for the monitoring infrastructure fulfills the EANPG conclusions and tasks, with the principle objective of ensuring that there are no gaps in the continuous availability or capability of the RVSM monitoring function and that there is no reduction in the RVSM safety.

Whilst the manner in which the proposed strategy would be achieved at a local level, in both Eastern and Western parts of the ICAO European Region, may differ, a common vision supporting the ICAO EANPG in its RVSM oversight responsibilities for 2020-2030 is shared by both the EUR RMA and the RMA EURASIA . The three step strategy is:

- **Step 1:** HMU monitoring infrastructure

  An HMU infrastructure currently enables all transponder equipped aircraft within their coverage area to be height monitored. This provides a means for all operators of RVSM approved aircraft to comply with monitoring requirements.

  A high level of operator compliance with MMR is currently achieved in Western Europe by the use of HMU. For the foreseeable future the only practical way to achieve the required level of monitoring, by all operators, is to continue to use HMUs. By adopting a similar approach for both the Eastern and Western parts of the region the proposed strategy will help achieve the same level of MMR compliance to be met in the Eastern part of the European ICAO region.

  Achieving this aspect of the strategy will depend upon separate local implementation policies, current configurations and geographical differences:

  Implementation policy for the EUR RMA:

  Maintain the existing HMU monitoring systems until the new ADS-B Height Monitoring System (AHMS) under development are capable of supporting the current level of MMR compliance (according to statement B EANPG Conclusion 1/2).

  Due to obsolescence issues the life-span of the current HMU systems is limited to between 5 and 10 years.

  Note: The situation is complex as the increasing problem of obsolescence within the exiting HMUs needs to be addressed and the ADS-B equipage rate is evolving.

  Discussions with the System Design Authority of the HMU have recently taken place regarding the anticipated duration over which the existing HMUs could remain operational. If the existing failure rates of key components continues in the manner already experienced then the use of components previously purchased to address obsolescence concerns should ensure the systems remain operational until at least 2025. However, it is to be noted that this is an assumption. Equipment failure rates could escalate in which case it may become necessary to prioritise the operation of one HMU over another. The alternative would be to incur the costs and time associated with developing, deploying, verifying and validating a new HMU or HMUs. The approach proposed is considered an acceptable compromise.

  Implementation policy for the RMA EURASIA :

  Continue the deployment of HMU monitoring tools on the Eastern part of the ICAO European region according to the Plan of development of the technical infrastructure

for the monitoring of height keeping aircraft performance to provide the same level of MMR compliance in the Eastern part of European ICAO region. .

Note: The final number and the deployed location of HMU stations in the Eastern part of the ICAO region will depend upon a range of factors including the size of the region, the ATC route structure, the traffic distribution patterns and the regional operators' opinion. The current phase of the implementation plan involves the installation of 4 HMUs. These HMUs are new so obsolescence should not be an issue for some time.

It is considered the minimum duration of step 1 is determined by the completion of a) and c) of step 2.

- **Step 2**: Develop and utilise an ADS-B Height Monitoring System (AHMS)infrastructure

The purpose of Step 2 is to establish the foundations for a, potentially, lower cost height monitoring system, based on ADS-B, which supports a more frequent monitoring of aircraft operating within a far wider volume of airspace. It provides the following:

a) 100% MMR compliance by all operators mandated to carry ADS-B (ED-102A/DO-260B avionics) within the European ICAO Region;
b) Continuous monitoring of all aircraft operating in European ICAO Region airspace;
c) Creating conditions to enable a reduction of the HMU infrastructure, which can, in step 3, be followed by a phased and managed removal of HMUs from operation;
d) A means to collect information about large height deviations (LHD) based on surveillance information for risk assessment.

Achieving this step will take in to account separate local implementation policies, supporting aircraft equipage mandates/legislation, current status and age of HMU configurations and geographical differences. It should be noted that the mandates may not be published or, if published, may not require all aircraft operating in designated RVSM airspace to equip with ADS-B. Therefore other monitoring methods will be required for this limited number of aircraft / operators.

Implementation policy for both RMAs:

The implementation policy for Step 2 is:

- Each RMA to be provided with sufficient applicable ADS-B data from across the airspace of the accredited States;
- Continue the HMU operation and data analysis in parallel with ADS-B data analysis;
- Analyse the potential use of ADS-B data to support LHD analysis and, if appropriate, to implement suitable procedures;

A transition to make increasing use of ADS-B data whilst complementing and supplementing the HMU data is foreseen. This would eventually lead to a stage where ADS-B data is a viable alternative data source for the majority of the fleet operating in Europe.

The estimated implementation timescale to conclude Step 2 will be determined by a number of factors. These include the time taken to develop ASE software tools capable of interfacing to and exploiting the ADS-B data, the time taken to develop/deploy an ADS-B surveillance network and the availability of a suitably equipped aircraft population. These two latter factors are largely outside the scope of the RMAs as they will depend upon equipment mandates, requirements and enforcement.

Based upon an assessment of current factors it is considered that the date by which ADS-B could be used as a data source comparable to HMUs in the Eastern and Western parts of the Europe, and Step 2 could conclude, would be 2025-2026.

- **Step 3**: Ensuring the Operation of the HMU and AHMS Monitoring Infrastructure Based Upon Cost Benefit Analysis:

The purpose of Step 3 is to address obsolescence issues and to reduce the costs of monitoring whilst achieving full compliance with monitoring requirements.

The estimated implementation date for the beginning of Step 3 is after reaching goal c) of Step 2 and in accordance with completion of conditions of Implementation policy in the different areas.

Implementation policy for the EUR RMA

In the Western part of the ICAO region phasing out of the HMUs is anticipated to start in approximately 2025 although this is dependent upon aircraft ADS-B equipage levels and the continued availability of HMU spare parts. Once all HMUs have been removed from service the operators of those Non-ADS-B equipped aircraft will need to revert to alternative mechanisms for achieving their height monitoring obligations.

Implementation policy for the RMA EURASIA

The long-term and efficient operation of HMU stations in the infrastructure of the technical monitoring equipment in the EURASIA RVSM region will be ensured by their simultaneous use for air traffic services as part of the national network of multi-lateration systems for aircraft surveillance in the airspace of the Russian Federation.

The long-term retention of HMUs within the EURASIA infrastructure will depend upon the widespread availability of data from aircraft equipped with ADS-B avionics.

The strategy outlined above involves the joint operation of two types of monitoring system for a significant proportion of the timeframe in question - one of them uses the information from multi-lateration systems, the other exploits ADS-B broadcasts. Each system will complement the other and may also be used for cross-verification between the systems.

8 With Regard to the Proposed Strategy

A strategy needs to balance the needs, pros, cons and costs of the proposals. The needs are defined in COG 74 RCOG 11 Conclusion 1/2. The following expands upon other aspects to be considered in the evaluation.

8.1 Potential Benefits

The potential benefits to such an approach are:

- Wider geographic extent of the monitoring volume,
- Whilst the initial development / deployment costs will introduce costs in the short term it is predicted to be cheaper in the long run based upon a number of metrics.
- Increased number of monitoring reports and aircraft monitored,
    - Despite operators meeting their requirements there are multiple aircraft never monitored.
    - It is estimated that approximately 800 aircraft operating in Western Europe have not been monitored.
    - Whilst not significantly reducing the cost of monitoring an aircraft is would leads to an improvement in safety through the early detection of anomalous aircraft behaviour.
- Earlier identification of aircraft with problematic avionic configurations,
- Simplified processes for aircraft operators to achieve fleet / aircraft monitoring targets.
- Monitoring aircraft across a wider volume of airspace would ensure that more aircraft are monitored more frequently. Not only would this mean that anomalous avionic performance is detected, and resolved, at an earlier stage it would also contribute to an improvement in safety of operations in airspace that is, over time, becoming increasingly traffic dense.
- No gaps from the current situation
- Possibility to fulfil the existing requirements
- The DTMS approach, where two different technologies are employed to assess ASE, provides a mechanism for the cross-verification of data.
- Correspond to the world trends and precedents set elsewhere in the RMA community.

8.2 Potential Consequences

A Strategy needs to balance the advantages and the disadvantages. The disadvantages foreseen to this approach stem principally from delays to the ADS-B deployment.

- Delays in ADS-B equipage may necessitate the development of a new generation HMU for deployment in Western Europe – as obsolescence and equipment failures may take one or more HMUs out of service. Alternatively an HMU station may become a source for spare parts for the remaining sensors – thus degrading the coverage currently achieved.
- In Western Europe the EUR RMA will need to develop systems to accept and process the ADS-B data for use on ASE assessments.
- Non-ADS-B equipped aircraft may need to re-route to fly within the coverage volume of an HMU, or incur the cost of a GMU measurement.

8.3 Costs

Costs will be dependent upon the local regions.

For the EUR RMA the additional cost would relate to the development of the ADS-B processing as the annual M&S costs are not expected to evolve significantly. Some budget provision is foreseen

for the years 2020-2022 to cover the development of software tools. It is anticipated that ADS-B data will be sourced for a separate EUROCONTROL monitoring programme and would thus be available at no extra cost. (The monitoring programme is looking to deploy more than 80 ADS-B receivers from 2019. If the eventual coverage obtained from these units is insufficient then either further units could be deployed, data could be sourced from ANSPs or other sources).

For the RMA EURASIA the proposed strategy is already in line with existing plans.

9 Conclusion

This paper describes a simple 3 step strategy for a monitoring infrastructure that fulfils the EANPG conclusions and tasks, with the principle objective of ensuring that there is no reduction in the RVSM safety and that there are no gaps in the continuous availability or capability of the RVSM monitoring function. It addresses immediate requirements whilst establishing a basis for the longer term activities to be conducted.

Whilst the manner in which the proposed strategy would be achieved at a local level, in both Eastern and Western parts of the ICAO European Region, may differ, a common vision supporting the ICAO EANPG in its RVSM oversight responsibilities for 2020-2030 is shared by both the EUR RMA and the RMA EURASIA.

A1. Annex 1: Considerations of a Local EUR RMA HMU Replacement Strategy

Whilst ADS-B can, increasingly, be used as a supplementary data source a requirement exists to cope with the transition to a fully ADS-B environment. As this is likely to be some years off some form of HMU infrastructure will be required for the coming period of time – say 5 to 10 years. Such a time frame would support the operators of any fleet with non-ADS-B equipped aircraft and would also support a managed transition to an ADS-B based ASE assessment.

For the EUR RMA the situation is more complex than in other States as the increasing problem of obsolescence also needs to be addressed. The options pertaining to managing the HMUs are:

- Option 1: Retain the existing HMU Infrastructure in its current configuration.
- Option 2: Develop and deploy a single new HMU.
- Option 3: Replace 2 HMUs.
- Option 4: Replace all 3 HMUs.
- Option 5: Supplement the HMU infrastructure with ADS-B assessment capabilities.
- Option 5A – for a volume of airspace similar to that of the HMUs (probably sourced from an ADS-B receiver dedicated to RMA operations
- Option 5B – for all of Europe (probably data sourced from ANSPs and other ADS-B monitoring programmes)

Options 1-4 are to be considered in parallel to supplementary mechanisms allowing the data to be compared with ADS-B (Option 5).

- Option 1: Retain the existing HMU Infrastructure
  - Do not develop and deploy a new HMU rather trust the existing infrastructure remains operational.
    - Discussions with INDRA and an assessment of the failure rates experienced for the equipment indicate that the 3 HMUs could continue to operate, in their current configuration for 5 to 7 years.
    - There is some risk associated with equipment failure but, should component obsolescence become problematic then a prioritised removal of service of an HMU station to make a spares provision for the HMU that serves the most aircraft could be performed. (Sacrificing one HMU station to make components available for another).
    - There may also be a commercial risk that INDRA consider the support of the HMUs to be outside their business model and chose not to tender for future contracts. There is no current indication that they will adopt this stance.
    - A lifetime purchase for key components to support the continuation of some form of HMU infrastructure took place some years ago and a gradual attrition is using up the current stores.
    - A mid-life upgrade to other certain key sub-systems could be considered – probably on the basis of when a failure occurs:
      - E.g. microwave links or servers could be replaced if failed / upgraded to overcome obsolescence.

  If the date by which a transition to ADS-B is expected to exceed 2025 then consideration will need to be made with regard to Options 2-4.

- Option 2: Develop and deploy a single new HMU:

- It is likely that retaining an EUR RMA HMU infrastructure for more than a period of approximately 5 to 7 years will require the development of a new generation HMU to replace one or more of the existing HMUs.
    - This will require a minimum period of 2 year for the development and deployment cycle, followed by 6 months of setting to work, testing, verification and validation before acceptance.
    - The new HMU would be deployed at Nattenheim as the coverage volume from that point captures more aircraft that either of the other two sites.
    - As replacing a single HMU does not meet the request of the ICAO EANPG there should also be a consideration of whether deployments of new EUR RMA HMUs should also take place at Lintz and Geneva will be required.
        - This would be based upon the numbers of aircraft that are monitored via the ADS-B approach and how many Non-ADS-B equipped aircraft would need to deviate to fly over Nattenheim to be monitored.
    - Microwave links, servers etc considerations etc…..
    - A Rough Order of Magnitude cost of approximately 2MEU should be anticipated.

- Option 3: Replace 2 HMUs
    - As option 2 but with addition cost of approximately 1 MEU
- Option 4: Replace all 3 HMUs
    - As option 2 but with addition cost of approximately 2 MEU

In Options 2 to 4 it should be noted that equipment failures may necessitate the prioritisation of one HMU over another prior to the time a new HMU is deployed.

- It is to be clarified whether such a degradation would be acceptable to the ICAO EANPG.
- Some operators could incur an additional cost if they were then required to fly over another HMU in order to be monitored. One could follow a similar stance adopted by the FAA regarding ADS-B equipage in that ‘Best Equipped are Best Served’- as ADS-B equipped aircraft would be monitored from the deployment of Option 5.

- Option 5: Develop an ASE Assessment Capability Based Upon the Use of ED-102A / DO-260B ADS-B Data.
    - Other decisions will be whether to produce our own software or base it on the FAA code.
    - A period of 2 years should be anticipated for the specification, procurement, development, coding, testing, integration etc. of new functionality.
    - The source of ADS-B data is to be considered:
        - Would it be from dedicated ADS-B sensors dedicated to the EUR RMA or from a general data repository or other sources? (Note the potential use of other sensors being deployed to support 1030/1090 MHz RF monitoring within the NM IR).
        - What should the coverage volume be? (Preferably far wider than that of the current HMUs – so Option 5B would be preferred).
        - Interface formats etc.
        - Should the assessment be made on the data from individual sensors or from a consolidated input? i.e. a single ADS-B ground-station or a consolidated system track e.g. from an ADS-B server

The following table, Table 1, can be used to support an assessment of which of the HMUs operated by the EUR RMA are the 'most efficient' i.e. which monitor the most aircraft.

Figure 1 Number of Aircraft Monitored by 2 or More HMUs of the EUR RMA

Counts Over the Period 1.1.2018 to 16.6.2018	3 HMUs (No Exclusions)	2 HMUs (Excluding LINZ)		2 HMUs (Excluding NATTENHEIM)		2 HMUs (Excluding GENEVA)	
	Number.	Number.	Percentage Lost Without LINZ	Number.	Percentage Lost Without NATT.	Number.	Percentage Lost Without GVA.
No. of Unique Aircraft	14389	13654	5,11%	13465	6,42%	13216	8,15%
No. of Unique Operators	2596	2477	4,58%	2353	9,36%	2175	16,22%
no. of Measurements	1678151	1269486	24,35%	1042223	37,89%	1044597	37,75%
Numbers of Operators							
European	1167	1120	4,03%	1122	3,86%	1068	8,48%
Non-European	1429	1357	5,04%	1231	13,86%	1107	22,53%
Combination of Operators and different ICAO aircraft types							
European	2420	2322	4,05%	2326	3,88%	2240	7,44%
Non-European	2193	2047	6,66%	1883	14,14%	1756	19,93%
Total	4613	4369	5,29%	4209	8,76%	3996	13,38%

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