Altimetry System Error (ASE) Workshop

13-15 September 2016

Summary

1. Executive Summary

1.1. The Federal Aviation Administration (FAA) and Eurocontrol hosted an Altimetry System Error (ASE) Workshop at the William J. Hughes Technical Center September 13-15, 2016. The effort was conducted under USA/EUROPE via a Memorandums of Cooperation FAA-Eurocontrol Cooperative Research Agreement Action Plan 03 (AP03): Air Traffic Modeling Separation Standards. The workshop was attended by Airlines including United, Southwest; aircraft manufacturers including Airbus, Boeing, and Embraer, and sensor manufacturers including Thales, UTAS, Honeywell, Curtis Wright Defense Systems, and Aeromech. Other government attendees included FAA Flight Standards, members of the US Navy RVSM team, and representatives from the South African CAA. Topics addressed included Regional Monitoring Agency (RMA) functions assigned to the FAA (ANG-E61), ASE monitoring and large ASE cases, details of the European Monitoring Agency (EUR RMA) recent monitoring and issues, aircraft and maintenance design by manufacturers, and detailed sensor design and failure mode analysis.

1.2. The workshop began with presentations provided by members of the Separation Standards Analysis Branch, ANG-E61. The presentations provided and in-depth view of the technical and analytical work performed by the Branch with respect to monitoring, tracking and reporting ASE performance of aircraft Groups and individual airframes. The presentations touched on the Branch's roles and responsibilities as mandated by International Civil Aviation Organization (ICAO) and FAA requirements, monitoring systems developed and maintained by the Branch, data processing and quality control measures, ASE performance monitoring and tracking, large ASE reporting processes and resolution collaboration with Flight Standards Service (AFS), operators and manufacturers.

1.3. The workshop continued with presentations of several large ASE case studies. The purpose of the presentations was to inform participants of contributing factors to large ASE performance, detail the large ASE detection process for each case, solicit feedback of possible solutions for unresolved cases, stimulate conversation between operators, manufactures, service providers and regulatory authorities, provide experiences gained from resolution collaboration with relevant parties and share lessons learned. Each case presented included figures of plotted data illustrating airframe ASE performance, details of causal factors, resolution strategies and, if resolved, figures showing improved performance.

1.4. Following review of large ASE cases, operators, manufacturers, and technical service providers had an opportunity to present on a variety of topics relevant to ASE performance. Topics presented by industry included troubleshooting poor ASE performance, the effect of implementing multiple modifications to a single airframe, long-term stability of aircraft components and systems that affect ASE performance, systematic altitude error and static error correction (SSEC) and random altitude error and estimation.

1.5. The workshop concluded with a series of breakout sessions. Each breakout session, ASE Quality Analysis, Pressure Surface Determination, ASE Data Elements, and Maintenance and Procedure Refinements, was designed to address target areas of interest of all participants. The intent of each workshop was to address each subject area at more refined level and to engage participants in a working group type of environment. Each participant had an opportunity to participate in two of the four breakout sessions.

1.6. This first workshop held in North America was very successful in providing information to the community of interest, particularly in getting direct participation by US industry. All participants expressed a desire for FAA to host a follow-on workshop within approximately one year.

1.7. The workshop agenda is included in Attachment A. A list of attendees is included in Attachment B.

2. Discussion

2.1. RMA roles and responsibilities

2.1.1. José Pérez, ICAO RMA Coordination Group (RMACG) Chairman, presented an overview of RMA roles, responsibilities and ASE-specific activities. The overview included discussion of the ICAO regional planning process, ICAO entities responsible for global harmonization with respect to identification and assessment of safety objectives, RVSM-specific safety objectives, establishment of Regional Monitoring Agencies and their role in ongoing system performance and safety monitoring with respect to ASE.

2.2. ASE monitoring requirements

2.2.1. ASE monitoring requirements were presented by John Warburton, Manager, FAA Separation Standards Analysis Branch, ANG-E61, and Branch members with subject matter expertise in areas of applicability outlined in the presentation.

2.2.2. Data Elements and Issues

2.2.2.1. Elements total vertical error (TVE), where an aircraft is in reference to the pressure altitude of the assigned flight level, were discussed. These elements include displayed altitude, transponded altitude, and altimetry system error. The ASE calculation process was also detailed.

2.2.3. Monitoring Methods

2.2.3.1. An overview of the three monitoring methods available in North America was presented. The three methods are the GPS-based monitoring unit (GMU), the aircraft geometric height measurement element (AGHME), and automatic dependent surveillance-broadcast (ADS-B).

2.2.4. AGHME Quality Control

2.2.4.1. The AGHME quality control process was presented. Evaluation of the primary sources of ASE measurements, quality parameters, analysis frequency and control measures were described. Figures depicting comparisons of met surface, raw height, smoot height, ADS-B, and ASE data for individual sample flights monitored by the AGHME and ADS-B were shown. The figures illustrated correlation between the data elements and comparison between well-sampled and poorly-sampled flight paths. Quality parameter requirements in terms of operational (flight) and meteorological data and statistical quality evaluation triggers were also discussed.

2.2.5. ASE Watch List and Large ASE Reports

2.2.5.1. Maintenance of the large ASE watch list, reporting of unsatisfactory RVSM aircraft performance with FAA Flight Standards Headquarters and FAA Flight Standards safety inspectors responsible for safety oversight of RVSM operators by means of the ASE Report (ASE-R), and ASE-R collaboration between FAA and operators was presented by Rachel Stagliano, FAA Mathematician, ANG-E61. ASE-R purpose, goals and resolution processes were also discussed.

2.2.5.2. Participants indicated a desire for FAA to be proactive with reporting observed degradation in ASE performance and long-term trends. In other words, report the erosion on performance as soon as it is identified. Manufacturers and operators are eager to either remediate the issue or validate potential inaccuracies in data processing. FAA performs a thorough analysis in order to ascertain a high level of certainty of the error prior to reporting.

2.2.5.3. Participants requested, if possible, initial pre-briefings to include in-depth explanation of data provided and what differentiates the reported airframe from other airframes included in the analysis.

2.2.5.4. Participants also request a repository of successful actions implemented to improve ASE performance.

2.2.5.5. It was noted by FAA, that FAA Flight Standards, AFS, serves as the regulatory authority. The Separation Standards Analysis Branch advises AFS.

2.2.6. Meteorological Analysis

2.2.6.1. The description of meteorological (MET) data used for determination of flight level height for the calculation of ASE and MET data processes were presented by John Warburton. Correction between pressure and true altitude and flight level height estimation processes using MET data was also discussed.

2.2.7. RVSM Approval Database

2.2.7.1. Scott Ellis, FAA Program Analyst, ANG-E61, presented RVSM approvals database requirements and RMA data sharing practices. An overview of the RVSM approvals and monitoring status results available on the FAA's website was also presented.

2.3. ASE case studies

2.3.1. Normal case studies

2.3.1.1. Prior to reviewing large ASE case studies, several nominal cases were previewed for discussion. Part of the discussion included aircraft group performance requirements and review of figures containing plotted data derived from the AGHME and ADS-B monitoring systems for nominal ASE performance cases were presented. A few cases where a step change, a jump in continuous consistence ASE performance, were also presented.

2.3.2. ASE results for B737 fleet

2.3.2.1. Monitoring data for several large ASE B737 airframe operations was presented for discussion. B737s are split in two separate groups based on their expected ASE performance characteristics – B737CL and B737NG. Initial analysis examined the performance differences between these two groups.

2.3.2.2. ASE Group performance data was presented in a figure. The data included in the figure are based on AGHME measurements made over the period from December 2014 to February 2016.

2.3.2.3. ASE performance data specific B737CL and B737NG airframes was presented on two separate figures. The 737CL group airframe data shown illustrates an overall bias of approximately 40ft. Agreement among airframes in the group and across operators can also be seen. Furthermore, several operators have approximately zero mean across their fleet. The 737NX group airframe data shown illustrated an overall zero mean. Agreement among airframes in the group and across operators can be seen with the exception of several airframes across several operators demonstrating large ASE. These airframes became the focus of the presentation.

2.3.2.4. A set of data was produced for all airframes across several operator fleets within the B737NX group to investigate ASE performance history, to determine which aircraft had largest ASE or largest increasing. Several airframes within the data set exhibited ASE performance that was much larger that the core of the group, and were large enough to trigger issuance of an ASE-R.

2.3.2.5. Remedial actions implemented by the operators were summarized and presented. Each operator performed Boeing AMM task 34-21-00 to test the Air Data Modules (ADMs) on both primary systems. The test confirmed that both Air Data modules for the static source systems were out of tolerance. During the investigation, it was determined that this error developed over a period of 10 years of aircraft service. The systems were replaced and ASE performance resumed to be within an acceptable range.

2.3.2.6. Participants indicated that the AMM procedure to test the ADMs at RVSM equivalent altitudes is not a regularly scheduled procedure. Given the connection to ASE performance, this should be taken into consideration.

2.3.3. ASE results for B744-10 aircraft

2.3.3.1. ASE results for B744-10 aircraft indicating a potential issue with the number of non-compliant points and overall Monitoring Group bias were presented and it was noted that an apparent increase in the monitoring group bias is being observed. It was also noted that similar data continues to be observed by and reported to NAARMO by other RMAs.

2.3.3.2. A figure containing plotted ASE performance data collected for all observed B744-10 airframes over a period of time and grouped by operator and a figure illustrating Group mean and standard deviation were reviewed and discussed. Measurement comparisons of multiple aircraft types within an operator's fleet as well as comparisons between measurements collected by other RMA's monitoring systems were reviewed. The comparison data demonstrated consistency in terms of a bias in the B744-10 Group performance and indicated a potential increase of approximately -75ft – -100ft in ASE performance.

2.3.3.3. The FAA/NAARMO ASE remediation work plan was discussed. The work plan included provision of a set of set ASE-Rs to FAA Flight Standards, AFS-470 for coordination with manufacturers, tracking ASE changes during corrective actions, and sharing corrective actions with FAA and industry in an effort to develop a resource for aiding future large ASE remedies.

2.3.3.4. Corrective actions implemented were summarized by airframe. Some of the corrective actions included: an air data computer (ADC) accuracy test on both L and R systems, ATC transponder accuracy test for all RVSM altitudes, pitot static probe inspections, and altimetry system error tests. In some cases where tests indicated the aircraft component was performing out of tolerance, such as the ADC or the altimetry system, the systems were replaced and some improvement in performance was observed; however, the improvement was not sufficient to realize acceptable ASE performance.

2.3.3.5. Although remedial measures have been implemented by affected operators, ASE results calculated for the B744-10 Monitoring Group indicate a large and increasing bias. Large ASE cases were observed in measurements from multiple operators of aircraft in this Group. ASE-Rs were issued to the applicable operators and resolutions are being tracked by NAARMO. Only one of the cases has been resolved.

2.3.4. Case Study – A320 large ASE status update

2.3.4.1. Rachel Stagliano presented data supporting FAA concern specific to Airbus A320 aircraft ASE performance. The presentation also highlighted FAA interaction and cooperation with United Airlines, Jet Blue Airways and Airbus.

2.3.4.2. Figures containing 2015-2016 ASE performance data for A320 airframes grouped by operator were presented. A bias of approximately +200ft. - +300ft. is shown for several aircraft.

2.3.4.3. An additional figure containing plotted data for Group mean ASE performance and standard deviation for similar aircraft types indicates that A320 performance as a Group falls within the acceptable range.

2.3.4.4. ASE-Rs generated for 6 United Airlines (UAL) airframes were presented. UAL coordinated with FAA/NAARMO and Airbus to explore remediation strategies. The following actions were implemented: Air Data testing performed, skin waviness tests performed, static ports were changed, ops and leak checks performed, selectively replaced air data components, MCU replacement, and air data module replacement.

2.3.4.5. In one case, it was revealed that a factory installed plug remained in the static port after installation. It was speculated that the plug may have contributed to poor ASE performance. Following this presentation, Airbus presented data clarifying that a plug in the static port will not cause a degradation in ASE performance.

2.3.4.6. In summary, while some of the remedial actions improved ASE performance of the subject A320 airframes, overall performance was still out of tolerance. The FAA/NAARMO continues to work with United and Airbus on large ASE causal factors.

2.3.5. Case study ASE-R 055

2.3.5.1. A large ASE case study of a Cessna 560 Encore purchased new in 2004 and RVSM authorized since 2005 was presented. In design, all required maintenance for authorized RVSM operations was performed with no damage or modification history. Initial altimeter accuracy testing was performed.

2.3.5.2. Data collected from the AGHME monitoring system during the period of December 2007 through February 2015 was presented in a figure. The data indicated large ASE performance ranging from approximately +200ft. - +400ft.

2.3.5.3. An ASE-R was generated and submitted to the applicable Certification Management Office (CMO). The investigation triggered by the ASE-R revealed that the aircraft had been customized and did not meet RVSM design requirements. The modification, camera provisions had been added, was performed prior to issuance of Certificate of Airworthiness. The airplane was taken to the factory service center returned to standard configuration.

2.3.5.4. An additional figure containing historical AGHME monitoring data during the period of February 2012 – February 2015 and data collected during a GMU validation flight performed after the aircraft was returned to standard configuration was presented. Data collected during the validation flight indicated a satisfactory ASE performance of less than 100ft.

2.3.5.5. Given the timing of the aircraft modification with respect to issuance of the airworthiness certificate and RVSM implementation in the domestic U.S. and the notification coordination process implemented by the FAA/NAARMO, there were several lessons learned from this particular case study. Lessons learned resulted in a change in inspector guidance, a change in the FAA point of contact, increased support from the RVSM program office and modification of ASE trigger criteria.

2.3.6. Case studies – linear drift

2.3.6.1. Andrew Lewis of Eurocontrol presented an overview of the Eurocontrol height monitoring unit (HMU) infrastructure including site locations, configuration, and data verification processes.

2.3.6.2. Data compiled for several case studies were plotted and presented in separate figures. The figures illustrate drift in ASE performance, a jump in ASE performance and bi-modal split between aircraft systems.

2.3.6.3. Some participants questioned the cause of the observed drift. It was noted that ASE drift commonly associated with performance of older airframes modified for RVSM certification and it is not typical performance of newer aircraft.

2.4. Industry Maintenance Practices – Operators

2.4.1. Southwest Airlines

2.4.1.1. David Bunin of Southwest Airlines presented sample data derived from tests performed on set command values at RVSM representative altitudes. As noted, these tests are not part of routine scheduled maintenance, and were specifically conducted to investigate reported Large ASE issues. The command values included parameters for altitude and airspeed reported by the avionics on the Captain's side and First Officer's (FO) side on an aircraft. A target, or acceptable range, value for altitude and airspeed was also provided. The data revealed that in each case, values reported by the Captain's side were lower than values reported by the FO side and in at least one case, the Captain's side value was outside of the acceptable range.

2.4.1.2. In conclusion, this test may be considered for future ASE performance trouble shooting efforts.

2.4.2. United Airlines

2.4.2.1. A representative from United Airlines addressed the participants and summarized the operator's experience in collaborating with the FAA on ASE resolution strategies. The representative offered cooperation with FAA in responding to and addressing ASE issued highlighted in ASE-Rs, requested cooperation with manufactures as needed and affirmed United's desire and proactive stance in addressing ASE.

2.5. Industry Maintenance Practices – Manufacturers

2.5.1. Airbus

2.5.1.1. A presentation summarizing ASE troubleshooting efforts was presented by Benoît Dazet of Airbus. The presentation included details of altimetry systems for the: A300 and A310; A320 and A330/A340; and the A380 and A350 families. It was highlighted during the presentation of the configuration of the Airbus altimeter systems that, based on the configuration, a plug in the static port would not affect ASE performance.

2.5.1.2. The following actions are included in the Airbus ASE troubleshooting checklist: transducer accuracy check, pneumatic pipe leak check, fuselage and static port inspection, pin programming ADC input status, pitot and angle of attack inspection and accuracy test.

2.5.2. Embraer

2.5.2.1. Alicio Loth of Embraer provided feedback on a previously reported trend identified during data collection analysis performed by Eurocontrol, bi-modal behavior on some airplanes of the E-170/190 fleet. The presentation included a brief description/overview of the airplane systems, installation characteristics related to the subject, the analysis performed, results and the conclusion.

2.5.2.2. Figures containing plotted data collected during testing performed by Embraer on airframes demonstrating bi-modal behavior were presented. For each monitored airplane, the analysis consisted of separating monitoring points into two systems. Considering all of the monitoring points, it could be determined the AVG ASE and the AVG ASE + 3 STD DEV for both designated systems were within ASE tolerance.

2.5.2.3. In conclusion, no matter which criteria is used, the fleet performance regarding ASE data remains within required limits. The method used by Eurocontrol to monitor altimetry systems performance is more conservative regarding “AVG ASE + 3 STD DEV” criteria. A Bi-modal behavior should not be a concern on this fleet.

2.5.3. Boeing

2.5.3.1. A representative of Boeing addressed the participants and highlighted that Boeing aims to be proactive in addressing ASE performance and offered cooperation and collaboration with industry partners.

2.5.4. B737CL and B737NG Air Data System Design Differences

2.5.4.1. An overview of B737CL and B737NG design differences and how the differences may affect ASE was presented by Yaghoob Ebrahimi, an Operation Research Analyst for the FAA’s Separation Standards and Analysis Branch. A Boeing B737CL and B737NG design history, more specifically, the different types, combination and placement of pitot static systems was provided.

2.5.4.2. A figure containing plotted data for Group performance by aircraft type showed that the B737CL exhibits a larger ASE average and SD when compared to the B737NG.

2.5.4.3. It was highlighted that deterioration/erosion/corrosion of pitot static probes, components of the pressure transducer such as the ADC or ADM, and instability over time are common causes of increased ASE.

2.5.4.4. FAA issued a number of ASE-Rs to operators of B737 aircraft and continues to collaborate with the operators to troubleshoot large ASE occurrences.

2.6. Industry Maintenance Practices – Technical Services

2.6.1. Thales

2.6.1.1. Air data pressure sensor in-service experience was presented by Alain Verbeke, Air Data Product Manager, Thales. An overview of the pressure sensors manufactured by Thales was provided.

2.6.1.2. It was noted that a high accuracy pressure manometer is for acceptance testing in production and repair shop resulting in product performance of (+/- 0,25 hPa), close to the performance of the highest manometer standard.

2.6.1.3. Sensor long-term stability was addressed. The sensor designs target long-term stability with root cause analysis in design as well as in process accelerated ageing testing on sensors sets used to validate the design. In-service results are compared to accelerated ageing tests results. Stability is monitored during the production process for each sensor. A final acceptance test is performed.

2.6.1.4. In-service experience for the Piezzo Electric Sensor and the Silicon Chip Sensor was summarized.

2.6.1.5. In conclusion, aircraft fitted with latest generation ADM experience a limited number of Large ASE cases. For older aircraft, some ADMs may need to be removed from the aircraft for recalibration in Thales shop. Once recalibrated, the ADM recovers its nominal performance and a high level of stability, no other drift is expected.

2.6.2. Aeromech

2.6.2.1. Adrian Johnson of Aeromech presented a summary of how aircraft modifications impact ASE. Specifically, aerodynamic modifications near static sources, changes to RVSM flight envelope, and damage and repairs were addressed.

2.6.2.2. The effect of implementing multiple modifications to a single airframe were presented. A large radome under the aircraft, bubble windows near the static port and camera windows under the fuselage were installed in a King Air. The takeaway from this data is that the dual camera & bubble window configuration shows almost no difference in SSE from the cameras alone, but in combination with the radome, the bubble window results in a large SSE effect which makes that configuration impossible to certify as a group without an SSEC change.

2.6.2.3. In a case where an airframe operates in multiple aerodynamic configurations, it was found the impact of the radome was small enough that a single optimized SSEC could be used so ASE requirements would be met in both configurations.

2.6.2.4. Data representing the flight envelope for a small business jet that went through an engine upgrade and Gross Weight increase was presented. The increase in thrust and gross weight, and decrease in fuel consumption during climb result in a higher Maximum W/delta at FL410 and an increase in speed at Max Continuous Thrust. Expanded flight envelope date compiled for several small aircraft Groups was presented. The data revealed, for some aircraft Groups, there is no problem with expanding the flight envelope; however, for others, the Group will no longer meet Mean ASE requirements if the Maximum W/delta were increased.

2.6.2.5. A graph showing an increase in errors in altitude measurement as altitude increases was presented. It was noted that service providers do not have a lot of data on ADC performance above FL410, but it’s safe to assume the errors will continue to grow with altitude.

2.6.3. UTC Aerospace Systems

2.6.3.1. James Egberg, Aerospace Engineer of UTC Aerospace Systems, presented an overview of systematic altitude error & SSEC and random altitude error & estimation. Sample data was presented indicating that probes can be custom designed to minimize AOA effects caused by A/C aerodynamics. A probe can also be designed to reduce the magnitude of the Mach-based SSEC correction.

2.6.3.2. The presentation continued to discuss 3-Sigma random error including aircraft and probe manufacturing tolerances. It was highlighted that probe contour, placement, finish and alignment all have a significant effect on ASE performance. Skin waviness, steps and gaps and probe mounting also effect performance. Theoretical computation, wind tunnel and flight testing are performed to quantify the effect. Probes can be custom designed to minimize AOA effects caused by aircraft aerodynamics and to reduce the magnitude of the Mach-based SSEC correction.

2.6.3.3. In summary, the systematic error (Mean ASE) and random error (3-σ) can be estimated by analysis in the design of the altimetry system. Aerodynamic effects are the primary sources of ASE (especially at high Mach), while transducer accuracy is a minor source of error. There are many sources of error that must be accounted for in the evaluation of RVSM compliance. This requires extensive analytical effort and flight testing in order to show compliance to RVSM requirements.

2.7. Department of Defense RVSM Approvals

2.7.1. Adrianne Cooper of the Naval Air Systems Command (NAVAIR), a certification authority for Communication Navigation Surveillance/Air Traffic Management (CNS/ATM) functionalities for Navy and Marine aircraft presented an overview of the RVSM certification process for U.S. Navy military aircraft.

2.7.2. A Memorandum of Understanding (MOU) was signed between FAA and DoD 25 July 2001. The agreement governs the use of DRVSM Airspace by DoD aircraft and states: the FAA recognizes the DoD need to approve Single Altimetry Tactical aircraft for RVSM; these aircraft may be approved providing the altimetry systems meet the performance requirements of AC 91-85; and DoD agrees to follow periodic height-keeping performance monitoring required by FAA. Currently NAVAIR certifications include 7 certified Groups and 5 Groups in the certification approval process.

2.7.3. RVSM model Group certification requires a Continuation of Certification (CoC) or Re-certification (R-Cert) for: hardware changes, software changes, airframe modifications, and external stores changes. Changes are assessed by PMA209 RVSM SMEs to determine if CoC or R-Cert is required based on the changes to the RVSM certified configuration.

2.7.4. NAVAIR approvals are maintained in an Access database is maintained by the PMA209 Navigation team. The database contains: a table of monthly DoD AGHME reports from the FAA Tech Center, a table for each aircraft group with their Mode S and BuNos, queries for each aircraft group on their current monitoring period results and monitoring results since their initial certification. The database will eventually contain initial monitoring data.

2.8. Future Monitoring Systems

2.8.1. ADS-B Service Volume and Stations

2.8.1.1. An overview of the U.S. ADS-B service volume and stations was presented by Manuel Gonzalez of the FAA’s Separation Standards and Analysis Branch. A table including all of the ADS-B services stations was presented, there are currently 11 stations positioned in the U.S. providing, with the exception of a portion of Alaska, total coverage of the U.S, Guam and Puerto Rico.

2.8.1.2. A summary of data quantity and quality control processing was provided. Data are captured for approximately 1000 aircraft daily. The quality control measures applied to these data are: ASE less than 200, standard deviation of less or equal to 45, straight flight levels between 290 and 410, a NAC value of 8 or higher. The team is developing quality control for ADS-B/MET alignment; localized areas of high MET gradients can cause incorrect high ASE values.

2.8.2. ADS-B independent sampling

2.8.2.1. An overview of ADS-B independent sampling was presented by Jennifer LeBlanc, Mathematician, FAA Separation Standards Analysis Branch.

2.8.2.2. Several figures depicting plotted ADS-B ASE position tracks for randomly selected GLF6 and GLF4 aircraft were presented. A green line indicated a compliant average ASE values with an average ASE track value that is <=160. A yellow line indicated an aberrant average ASE value with an average ASE track value that is >160 but <=199. A red line indicated a non-compliant average ASE value with an average ASE track value >=200. Most of the figures included green lines where compliant ASE values were observed; however, a red line and a yellow line were present on one of the figures. This overview demonstrated how aberrant ASE could be observed, and was correlated with airframes that had been issued ASE-Rs or that were on the RMA watch list. More work is needed to independently sample the ADS-B – ASE flight track, and this will be completed by the Separation Standards Analysis Branch over the next year.

2.8.2.3. In conclusion, with ADS-B we have a greater ability to observe ASE, FAA is still in the process of developing a procedure for ADS-B independent sampling, use of ADS-B, will provide the ability to build an ASE profile as a function of speed and altitude and perhaps develop an error calibration curve into ASE calculation.

2.9. Breakout Session – ASE Quality Analysis

2.9.1. Aircraft Geometric Height Element (AGHME)

2.9.1.1. Louis Delemarre, Lead Engineer of the Concepts & Systems Integration Branch presented a detailed description of the FAA's ground-based monitoring system – AGHME and an in-depth view of the system's multi-lateration functionality. An image depicting the five elements and the logical central node that comprise an AGHME constellation was presented. A diagram of the system data flow and processing was also presented. The timestamp difference of arrival time of a common signal from an airframe, the algorithm to produce "matched set" of timestamps to input into geometric the height model, geometric heights converted into pressure altitudes and computation ASE was discussed in detail.

2.9.1.2. AGHME time specifications and time receipt analysis results were also discussed. A series of time receipt analysis figures illustrating the number of hits by recorded time in nanoseconds. The presentation concluded with a figure containing similar data representing a new time receipt analysis procedure resulting in a better yield.

2.9.2. AGHME Data Integrity

2.9.2.1. Salvatore Mazza, technical support for ANG-E61, presented a summary of the control measures and processes applied to data collected by the AGHME to ensure data quality and integrity. Count of unique aircraft IDs, average pulse amplitude of each Mode S message, number and percentage of contributions, data size and duplicate messages are elements factored into the data quality analysis process.

2.9.2.2. Sal also discussed system integrity monitoring controls. Some of the items monitored are digitizer and computer temperature, power supply, line power, shelter temperature, oscillator status and GPS fine steering.

2.10. Breakout Session – Pressure Surface Determination

2.10.1. Meteorological Algorithm

2.10.1.1. Eugene Fortunato, Mathematician, Separation Standards Analysis Branch, presented an overview of the meteorological algorithm including a description of meteorological data, flight level height estimation processes and flight level height implementation for the calculation of ASE.

2.10.1.2. The FAA uses the Wide Area Forecast System (WAFS) meteorological file provided by the National Oceanic and Atmospheric Administration (NOAA) Environmental Modeling Center (EMC) as source data. The data elements contained in this file were described in detail.

2.10.1.3. The flight level estimation, or pressure surface determination, was discussed. Equations for standard atmosphere pressure and height, WAFS input – height and temperature and flight level height estimation were presented.

2.10.1.4. Flight level height implementation for the calculation of ASE was presented. Elements of total vertical error (TVE) and flight level height as a function of aircraft position were also discussed in detail.

2.11. Breakout Session – ASE Data Elements

2.11.1. Data Analysis

2.11.1.1. A series of figures containing plotted data collected from the AGHME systems were presented by John Warburton. While similar to the data presented during day one, the breakout provided the opportunity for in-depth discussion of AGHME errors and performance expectations.

2.12. Breakout Session – Maintenance and Procedure Refinements

2.12.1. FAA Maintenance Programs

2.12.1.1. Marcus Labay, Aviation Safety Inspector Flight Standards Service - Avionics Branch, presented details on the FAA's RVSM maintenance program. It was noted that the initial RVSM maintenance program was developed by using Type Certificate Holder (TCH) Instructions for Continued Airworthiness (ICA). Program adjustments using TCH Service Bulletins (SB) Service Letters (SL) or ICA revisions and operator-initiated program adjustments were discussed.

2.12.1.2. The air carrier's Continued Analysis and Surveillance System (CASS), a risk-based closed-loop system, was also discussed. A figure containing plotted ASE measurements recorded for a single airframe for a period of one year was presented. The figure showed improvement in ASE performance from approximately -300ft. to less than -100ft. The improvement was the direct result of maintenance performed on the airframe and successful implementation of CASS.

2.12.2. RVSM Monitoring Groups

2.12.2.1. Andrew Lewis discussed the roles of an RMA applicable to RVSM Monitoring Groups, the integration of Monitoring Groups into collision risk assessments and provided a detailed description of the three established Monitoring Groups. He further noted: RVSM Monitoring Group definitions are a unique configuration for the assessment of safety in RVSM airspace, the accuracy of annual collision risk assessments rely on the complete and accurate definitions of RVSM Monitoring Groups and Non-Group aircraft, which are not monitored, contribute an unknown risk to the safety of operations in RVSM airspace.

2.12.2.2. The processes and challenges of maintaining RVSM Monitoring Groups was discussed. It was highlighted that RVSM Monitoring Group definitions are maintained and updated by NAARMO and EUR RMA and that there is not a single common source for the information required to determine RVSM Monitoring Group constitution. Neither of these RMAs hold the necessary resources or expertise to evaluate technical performance specifications to determine RVSM Group content. It is in the interest of all operators, airworthiness authorities, manufacturers and RMAs to ensure that the RVSM Monitoring Group definitions are correct. RMAs hope to receive cooperation from these organizations to maintain the RVSM Monitoring Groups.

2.13. Future Developments

2.13.1. Aircraft certification considerations associated with the proposal to expand the upper limit of RVSM airspace were presented. Based on a Gander Oceanic Control Area (OCA) traffic sample collected during the period of April 2015 – March 2016, it was proposed during the twenty eighth Working Group meeting of the Separation and Airspace Safety Panel (SASP-WG/28) that the SASP undertake the necessary work to raise the upper limit of RVSM airspace to accommodate current and future aircraft operating capability. It was highlighted that certification, avionics and operational performance accuracy within the proposed upper limit should be taken into consideration before progressing with the proposal. Furthermore, an evaluation of the ASE budget is recommended.

2.13.2. In Conclusion, avionics changes may be required to support the proposed change. In the evaluation of increasing the maximum permissible RVSM altitude, it is important that the aircraft OEMs and/or design holders re-evaluate the RVSM flight envelope and assess the ASE levels at these new (higher W/δ) flight conditions. Consideration of the upper limit of RVSM airspace should be based on the available aircraft and avionics performance data.

2.13.3. It was noted by industry participants that degradation in performance of some avionics components can be expected above FL410, because their design had been optimized for performance up to FL410. A figure included in the Aeromech presentation provides several examples. It was also noted there is very little operational or meteorological data for operations above FL410 to make a proper assessment; however, it is expected that errors will increase with altitude.

2.13.4. Participants also questioned the operational need for increasing the upper limit of RVSM highlighting many aircraft have an operational ceiling close to FL410.

Attachment A

ASE Workshop Agenda

Day 1 – Tuesday September 13th

Topic	Presenter(S)	Filename
Welcome	Michael Greco, FAA	
Introductions	John Warburton, FAA Andy Lewis, Eurocontrol	Meeting Intro
Tour De Table	All	Participant List
ASE Overview RMA Roles And Responsibilities Global And International Harmonization Safety Objectives Establishment Of Regional Monitoring Agencies (RMAs) RMA Duties And Responsibilities RMA ASE-Specific Activities	José Pérez , FAA	1.1_RMA Overview
ASE Monitoring Requirements Data Elements And Issues Monitoring Methods AGHME Quality Control Watch List And Large ASE Reports Metrological Analysis RVSM Approvals Database	John Warburton, FAA	1.2_ASE Monitoring
ASE Case Studies		
Normal Cases	John Warburton, FAA	1.3_Nominal ASE Observations
Observing ASE – 737 Fleet	John Warburton, FAA	1.4_737 ASE Observations
Observing ASE – B744	John Warburton, FAA	1.5_B744 ASE Observations

Day 2 – Wednesday September 14th

Topic	Presenter(S)	Filename
ASE Case Studies, Cont		
Airbus 320	Rachel Stagliano, FAA	2.1_A320 Large ASE Update
ASE-R 055	Charles Fellows, FAA	2.2_ASE-R 055
HMU Infrastructure and ASE	Andy Lewis, Eurocontrol	2.3_EUR RMA HMU and ASE
Industry Maintenance Practices		
Airbus: Troubleshooting ASE	Benoît Dazet, Airbus	2.4_Airbus Troubleshooting
B737CL & B737NG Design Differences	Yaghoob Ebrahimi, FAA	2.5_B737 Design Differences
Southwest: Testing Set Command Values	David Bunin, Southwest	NA
Embraer : Bi-Modal ASE Behavior	Alicio Loth, Embraer	NA
Thales Avionics: Sensor Performance	Allain Verbeke, Thales Cyprien Bros, Thales	2.6_Thales_Sensor
Aeromech: Aircraft Modifications	Adrian Johnson, Aeromech Tony Wiederkehr, Aeromech	2.7_AeroMech_Modifications
UTC: Design For RVSM Compliance	James Egberg, UTAS UTC	2.8_UTC_Design for RVSM
DoD: RVSM Approvals	Adrianne Cooper, Navair	2.9_DoD_RVSM Approvals

Day 3/Breakout Sessions – Thursday September 15th

Topic	Lead/Facilitator	Filename
Future Monitoring Systems		
Ads-B Independent Sampling	Jennifer Leblanc, FAA	3.1_Future Monitoring ADS-B
Future Monitoring Options/ ADS-B	Manuel Gonzalez, FAA	3.2_ADS-B ASE Processing
Breakout Session: 1 ASE Quality Analysis	John Warburton, FAA	1.2_ASE Monitoring
Breakout Session: 2 Pressure Surface Determination	Eugene Fortunato, FAA	B2_Met Algorithm
Breakout Session: 3 ASE Data Elements	Lou Delemarre, FAA	B3_AGHME Constellations
Breakout Session: 4 Maintenance And Procedure Refinements	Marcus LaBay, FAA Andrew Lewis, Eurocontrol	B4_Maintenance Programs B4_RVSM Monitoring Groups
Future Developments		
Operations Above Fl410	Stephanie Beritsky, TertraTech	3.3_Upper Limit RVSM Airspace 3.4_3.4_SASP-WG 28-FLIMSY 03
Additional Presentations	**Lead/Facilitator**	**Filename**
China RMA: LTHM Program	NA	A1_China RMA_LTHM Program

Attachment B

List of Participants

First	Last	Company/Organization	Email
Cyprien	Bros	Thales Group	cyprien.bros@fr.thalesgroup.com
Philip	Brown	Curtis Wright Defense	pbrown2@curtisswright.com
David	Bunin	Southwest Airlines	david.bunin@wnco.com
Ross	Burton	CSSI	rburton@cssiinc.com
Frank	Bushman	US Navy	frank.bushman.ctr@navy.mil
Michael	Chmutov	CSSI	michael.ctr.chmutov@faa.gov
Dean	Conner	United Airlines Avionics	dean.conner@united.com
Adrianne	Cooper	US Navy	adrianne.cooper@navy.mil
Robert	David	US Navy	robert.p.david@navy.mil
Benoit	Dazet	Airbus	benoit.b.dazet@airbus.com
Edward	deBrabander	US Navy	edward.debrabander@navy.mil
Eduardo	DeSantis	EMBRAER	eduardo.santis@embraer.com.br
Benoit	Duquesne	Airbus	benoit.b.duquesne@airbus.com
Yaghoob	Ebrahimi	FAA	yaghoob.ebrahimi@faa.gov
James	Egberg	UTC Aerospace Systems	james.egberg@utas.utc.com
Scott	Ellis	FAA	scott.ellis@faa.gov
Christine	Falk	FAA	christine.falk@faa.gov
Reba	Fauntleroy	CSSI	reba.ctr.fauntleroy@faa.gov
Charles	Fellows	FAA	charles.fellows@faa.gov
Blaney	Fisher	Boeing ADS	blaney.fisher@boeing.com
Bennett	Flax	CSSI	bennett.ctr.flax@faa.gov
Gene	Fortunato	FAA	eugene.fortunato@faa.gov
Manuel	Gonzalez	FAA	manuel.gonzalez@faa.gov
Terrance	Harris	SA CAA	harrist@caa.co.za
Brian	Hawley	UTC Aerospace Systems	brian.hawley@utas.utc.com
Colleen	Horan	FAA	colleen.horan@faa.gov
Adrian	Johnson	Aeromech	acj@aeromechinc.com
Marcus	LaBay	FAA	marcus.a.labay@faa.gov
Jennifer	LeBlanc	FAA	jennifer.leblanc@faa.gov
Andrew	Lewis	EUROCONTROL	andrew.lewis@eurocontrol.int
Brian	Livings	FAA	brian.livings@faa.gov
Alicio L.	Loth Jr	EMBRAER	alicio@embraer.com.br
Sal	Mazza	CSSI	salvatore.ctr.mazza@faa.gov
Bob	Miller	CSSI	rmiller@cssiinc.com
Eric	Mork	Boeing ADS	erik.a.mork@boeing.com
James	Mosley	Honeywell	james.mosley@honeywell.com
Cyndy	Newcomb	CSSI	cynthia.ctr.newcomb@faa.gov
Jose	Perez	FAA	jose.perez@faa.gov
Timothy	Quinn	US Navy	timothy.quinn1@navy.mil
Kentse	Ramavhoya	SA CAA	ramavhoyak@caa.co.za
Prewitt	Reaves	Southwest Airlines	prewitt.reaves@wnco.com
Ronaldo	Rogeri	EMBRAER	ronaldo.rogeri@embraer.com.br
Amandine	Rojon	Airbus Operations SAS	amandine.rojon@airbus.com
Jennifer	Rowles	Alpha Native	jennifer.ctr.rowles@faa.gov
Robert	Rushlow	FAA	robert.g.rushlow@faa.gov
Luis	Santiago	ARINC	lsantiag@arinc.com
Ken	Schmidt	United	ken.schmidt@united.com
Tracy	Sivley	CSSI	tracy.ctr.sivley@faa.gov
Steve	Smoot	SAIC	steve.ctr.smoot@faa.gov
Rachel	Stagliano	FAA	rachel.stagliano@faa.gov

First	Last	Company/Organization	Email
Timothy	Thompson	US Navy	timothy.thompson@navy.mil
Ahmad	Tokiy	Afghanistan CAA	hakimi.airworthiness@acaa.gov.af
Alain	Verbeke	Thales Group	alain.verbeke@fr.thalesgroup.com
John	Warburton	FAA	john.warburton@faa.gov
Tony	Wiederkehr	Aeromech, Inc.	tcw@aeromechinc.com