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Agenda Item 4: Optimum capacity and efficiency – through global collaborative ATM
4.1: Efficient management of airspace and improved flow performance through collaborative decision-making (CDM)

UNITED STATES CONSIDERATIONS FOR AVIATION SYSTEM BLOCK UPGRADE MODULES RELATED TO AIRBORNE COLLISION AVOIDANCE SYSTEMS

(Presented by the United States)

EXECUTIVE SUMMARY

This paper presents the United States considerations for implementation of the aviation system block upgrades (ABSUs) related to airborne collision avoidance systems (ACAS). In response to direction by the 37th Session of the ICAO Assembly, the Organization established ABSUs to facilitate global harmonization and interoperability with respect to airspace.

Two ABSU modules relate to airborne collision avoidance, Module B0-101: ACAS improvements and Module B2-101: New collision avoidance system. The U.S. Federal Aviation Administration (FAA) research has examined the benefits and feasibility of both modules. This research indicates that incremental improvements to the existing ACAS will not provide substantial benefits in U.S. airspace. However, research shows significant operational and safety benefits from development of a new collision avoidance system. The FAA is developing a new collision avoidance system (ACAS X) which uses new advances in dynamic programming to produce threat resolution advisories that reduce alert rates and improve safety. Given these findings, and in light of budgetary constraints, the FAA will give priority to ACAS X development in support of ABSU Module B2-101.

Action: The Conference is invited to agree to the recommendation in paragraph 3.2.

1. INTRODUCTION

1.1 The Conference has been informed in AN-Conf/12-WP/3 of the updated *Global Air Navigation Plan* (Doc 9750) and the concept of aviation system block upgrades (ASBUs). The ABSUs support a framework of individual modules that describe solutions or upgrades of the global air traffic management (ATM) system along with equipage implications and transition plans. Block 0 represents short-term improvements to existing equipment; Block 1 is comprised of improvements for the year 2018, Block 2 targets 2023 and Block 3 beyond 2028.

1.2 The Conference has been further informed in AN-Conf/12-WP/12 of the proposed modules directly related to ACAS. Module B0-101: ACAS improvements, describes potential improvements to the existing ACAS capability and Module B2-101: New collision avoidance system, describes development of a future replacement system.

1.3 This paper describes on-going U.S. work related to Modules B0-101 and B2-101 and provides information on future U.S. plans to achieve the desired increases in operational capability.

2. ACAS-RELATED MODULES

2.1 **Background.** Airborne collision avoidance system (ACAS) II has been mandated internationally by ICAO since 2003 on large turbine powered aircraft and is a mature system. Traffic alert and collision avoidance system (TCAS) v6.04a was introduced in the early 1990s. Based on airspace changes such as reduced vertical separation minimum (RVSM) and the need for operational improvements, revised standards for TCAS v7.0 (ACAS II) were approved in 1997. In response to observed issues with TCAS reversal logic and pilot confusion over auditory annunciations, standards for TCAS v7.1 were approved in 2009 and adopted into the ICAO Standards and Recommended Practices (SARPs) in 2010.

2.1.1 *ACAS operational experience.* ACAS II is an effective safety system; however, further improvements beyond TCAS v7.1 are desired by the operational community. Safety studies show that ACAS II reduces mid-air collision risk by 80 – 95 per cent and operational monitoring of ACAS Resolution Advisories (RAs) indicates that ACAS is largely operating as designed. However, many RAs may be considered "unnecessary" RAs since they reflect interactions between normal, safe airspace procedures and ACAS alerting logic and are not necessarily representative of potential conflicts. For example, U.S. TCAS monitoring data indicate over 75 per cent of RAs in the U.S. are the result of such interactions with over 50 per cent of all RAs being associated with 500 ft instrument flight rules (IFR)/visual flight rules (VFR) vertical separation; ~7 per cent of RAs associated with 1 000 ft IFR/IFR level off geometries; 12 per cent occurring during visual parallel approach operations and another 15 per cent occurring in the VFR traffic pattern. European airspace has significantly less interaction between IFR and VFR traffic; this is reflected in monitoring data indicating that over 50 per cent of RAs in European airspace are due to IFR/IFR 1 000 ft level off geometries. The operational community has expressed a desire to reduce the negative interaction between ACAS alerting criteria and current or future airspace procedures.

2.1.2 *ACAS in the future airspace system.* Research indicates that ACAS alerting will not support some future airspace procedures that result in reduced separation and/or problematic geometries. In particular, current ACAS will not support 3 NM enroute separation, some passing in-trail procedures and closely spaced parallel operations. Additionally, there is a need to expand collision avoidance capability to new airspace users. Unmanned aircraft systems (UAS) currently lack a certified collision avoidance capability which will likely be required to facilitate unrestricted airspace access. Beyond UAS, general aviation safety will be enhanced by a cost-effective collision avoidance capability. However, many UAS and general aviation aircraft performance capabilities do not meet ACAS requirements. Finally, in order to provide a collision avoidance capability to these users and to improve overall system performance, the future collision avoidance system must incorporate automatic dependent surveillance — broadcast (ADS-B) surveillance data and should provide the capability to use surveillance sources such as electro-optical or infrared that may be employed on UAS. In summary, the future collision avoidance system must easily be adaptable (i.e. "tuneable") to accommodate new airspace procedures as they are introduced, provide capability to new user classes and incorporate additional surveillance information.

2.2 **Module B0-101.** This module describes short-term improvements to existing ACAS II to reduce the incidence of "unnecessary alerts" while maintaining or improving the existing level of safety.

2.2.1 In order to address these issues, a series of ongoing and proposed efforts have been initiated. Work in this area is focused on reducing the rate of "unnecessary" RAs during normal airspace procedures.

2.2.2 *Ongoing work.* Airbus is in the process of developing and certifying integration of TCAS TA/RA information into the aircraft autopilot/flight director system. These efforts include integrating ACAS RA information into the autopilot/flight director systems to allow for automatic ACAS RA response. Airbus is also developing methods to reduce commanded aircraft vertical rate upon receipt of a TA in some circumstances to avoid receipt of an RA (TCAP – TCAS alert prevention). Safety assessments using European encounter models and airspace models show that these functions may ensure safety and decrease alert rates. TCAP is intended to reduce unnecessary RAs in 1 000 ft encounters. Monitoring data shows that these 1 000 ft encounters constitute approximately only 7 per cent of RAs in U.S. airspace.

2.2.3 *Proposed work.* The Single European Sky ATM Research (SESAR) programme has begun research to examine changes to TCAS alerting parameters to reduce “unnecessary” RAs. Initial studies indicate that altering a subset of ACAS parameters may reduce alert rates in European airspace; however, studies using U.S. airspace models have found that altering ACAS vertical alerting thresholds to reduced alert rates in 500 ft IFR/VFR separation negatively affected safety (i.e. increase in risk ratio). Initial analyses of the specific SESAR proposal indicates it will have limited benefit in the U.S. and will primarily affect a smaller proportion of preventative RAs in 500 ft IFR/VFR encounters. Eliminating these RAs will have little effect on airspace capacity and efficiency since they do not require a change to the aircraft vertical profile.

2.3 **Module B2-101.** This module describes the need for a new collision avoidance capability to enable effective collision avoidance in the future airspace environment. In addition to observed “unnecessary” alerts in existing airspace, studies indicate that existing TCAS alerting criteria negatively interact with some future airspace procedures. In particular, closely spaced parallel operations (CSPO) or 3 NM enroute separation has been shown to result in excessive unnecessary RAs. An additional benefit of a future collision avoidance system is that it may be able to use additional surveillance information such as ADS-B and be more readily extendable to user classes such as general aviation and UAS than can be accommodated with TCAS II.

2.3.1 *Future ACAS Research and Development.* Since 2009, the U.S FAA has funded research and development of a future collision avoidance capability known as ACAS X. This system employs a new approach to collision avoidance which explicitly considers uncertainties in surveillance measurements, pilot response to alerts and the future state of ownership and intruders. ACAS X uses advanced dynamic programming techniques to optimize the required collision avoidance action based on these probabilities and a cost function which makes explicit required safety and operational considerations. ACAS X also incorporates a sensor-agnostic surveillance architecture and allows for use of ADS-B or other surveillance sources. This approach can be adapted for a wide range of aircraft performance and dynamics and can thus be used to extend collision avoidance capability to general aviation aircraft and UAS. Additionally, ACAS X also supports the capability to provide procedure-specific alerts against selected traffic participating in airspace procedures such as CSPO while retaining global collision avoidance protection against non-selected aircraft. Modelling and simulation studies show that ACAS X reduces RA frequency by over 30 per cent while improving risk ratio by approximately 50 per cent. ACAS X is also compatible with 3 NM enroute separation, and development of a procedure-specific variant is in development to enable CSPO operations by use of procedure-specific alerting.

2.4 **RTCA analysis.** RTCA SC-147, in conjunction with EUROCAE WG-75, evaluated the current and projected future shortfalls with existing ACAS and evaluated potential long- and short-term mitigations. This analysis was published as RTCA DO-337 in March 2012. In support of this study, the FAA has evaluated modifications to the existing ACAS vertical alerting threshold and found that this change produced modest reductions in alert rates, but would increase risk ratio and will have only limited operational benefit. This report provides the consensus conclusion that modifications to existing ACAS will not be sufficient to address current or projected shortfalls. As a result, this report recommends development of a future collision avoidance capability.

2.5 **United States ACAS plans.** The U.S. FAA has evaluated the potential for both improving current ACAS and developing a future collision avoidance capability. Given the limited resources available for research and development and the limited benefits obtained from modifications to current ACAS, the FAA has decided to pursue the future collision avoidance system – ACAS X in order to reduce unnecessary alert rates, improve interoperability with current and future airspace procedures and to extend collision avoidance capabilities to new user classes such as general aviation and UAS.

2.5.1 Reasons for pursuing a future collision avoidance system. Based on study and evaluation of the alternative of modifying existing ACAS or developing a new system, the FAA has chosen to focus on development of ACAS X. FAA analysis has determined that modification of existing ACAS to provide the desired capability would require a substantial effort and the future system could be delivered in a similar timeline.

2.5.1.1 Studies using U.S. airspace and encounter models show minimal benefit, and in some cases increased risk ratio (decreased safety) associated with the incremental improvements to existing ACAS proposed by SESAR. This is due to significant differences between U.S. and European airspace. In contrast, ACAS X has been shown to reduce unnecessary alerts and improve safety in both the U.S. and worldwide airspace. Additionally, ACAS X is compatible with 3 NM enroute separation and other airspace procedures.

2.5.1.2 Existing ACAS cannot easily ingest ADS-B surveillance or other surveillance sources. Given the tight coupling to existing transponder surveillance, adapting existing ACAS to use ADS-B surveillance or other surveillance sources is likely to require extensive study and analysis.

2.5.1.3 ACAS logic does not readily support collision avoidance for UAS or other aircraft that do not meet ACAS design assumptions. Modifying ACAS to support new user classes would require substantial effort.

2.5.1.4 ACAS X provides the capability to support operation-specific alerts for airspace procedures such as closely spaced parallel approach operations where different alerting thresholds may be provided against participating airplanes while retaining global protection against all other aircraft. Existing ACAS would require substantial modification to provide this capability.

2.5.1.5 Only one additional ACAS upgrade is likely to be supported by the user community in the next tne years. Since ACAS X can be fielded within 10 years, the FAA would prefer to focus its efforts on development of a more robust and capable system.

2.5.2 *ACAS X program plan.* An FAA flight test of the ACAS X threat resolution logic is planned for 2013 and work on the surveillance and tracking module is ongoing. Standards development work within RTCA may begin as early as 2014 and be completed by 2018. Following operational evaluation aboard participating partner aircraft, the first certified units could fly as early as 2020.

3. CONCLUSION

3.1 Existing ACAS requires modifications to be more compatible with current and future airspace procedures. The FAA has concluded that the proposed modifications to existing ACAS provide minimal benefit in the United States. Research and development of a future collision avoidance system, ACAS X, has been conducted since 2009. ACAS X has the flexibility to reduce unnecessary alerts, support use of alternative surveillance sources, enable future airspace procedures and provide a collision avoidance capability for new user classes. Therefore, the U.S. has chosen to exclusively focus on development of a future collision avoidance system. ACAS X has reached a state of sufficient maturity that international participation in research and development activities will facilitate acceleration of fielding a future collision avoidance capability.

3.2 The Conference is invited to agree to the following:

a) that ICAO incorporate ACAS X into its airborne collision avoidance work programme; and

b) States consider participating with the U.S. FAA in the development of ACAS X.

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