The future of collision avoidance – ACAS X

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Abstract *- Airborne Collision Avoidance System X (ACAS X) is a family of future collision avoidance systems. ACAS XA is intended to replace the current Traffic Alert and Collision Avoidance System for large aircraft as well as provide collision avoidance system for General Aviation (GA) and Unmanned Aircraft Systems (UAV). In this paper we present an overview of a next-generation onboard safety system and its extensions to other types of aircraft which have not yet been covered by collision avoidance systems.*

Keywords — *ACAS, TCAS, Collision Avoidance, Aviation safety*

I. INTRODUCTION

The Airborne Collision Avoidance System was introduced in order to reduce risk of mid-air collisions or near mid-air collisions between aircraft. It serves as a last-resort safety net irrespective of any separation standards. ACAS tracks aircraft in the surrounding airspace through replies from their ATC transponders. ACAS II interrogates the Mode C and Mode S transponders of nearby aircraft (‘intruders’) and from the replies tracks their altitude and range and issues alerts, to the pilot, as appropriate. Non-transponding aircraft are not detected. ACAS II works independently of the aircraft navigation, flight management systems, and Air Traffic Control ground systems. The carriage of ACAS II version 7.0 has been authorized in Europe since 1 January 2005 by all civil fixed-wing turbine-engined aircraft having a maximum take-off mass exceeding 5700 kg or a maximum approved passenger seating configuration of more than 19. Currently, the only commercially available implementation of ICAO standard for ACAS II is TCAS version 7.1 (Traffic alert and Collision Avoidance System).

II. ACAS STANDARDS

Types of ACAS which have been specified in ICAO Annex 10:

- ACAS I – which provides an aid to visual acquisition. ACAS I provides information to other traffic, Proximate Advisories (PA) and Traffic Advisories (TA) but does not include the capability for generating a “Resolution Advisory” (RA)
- ACAS II – provides vertical “Resolution Advisory” (RA) in addition to “Traffic Advisory”
- ACAS III – provides vertical and horizontal RAs in addition to TAs

Even though ACAS III is mentioned as a future system in ICAO Annex 10, ACAS III is unlikely to develop due to complications which the current surveillance systems have with horizontal tracking. In this paper I would like to focus on research which is currently being conducted to develop as a future collision avoidance system under the working name of ACAS X.

III. NEXT GENERATION OF COLLISION AVOIDANCE – ACAS X

ACAS X is an interoperable expansion of a family of aircraft collision avoidance systems developed for use in NextGen airspace. The United States Federal Aviation Administration (FAA) initiated formal research in 2009.[5] New approach is based on decision theoretic safety logic, flexible surveillance tracker and other technologies to generate alerts using an off-line optimization of RAs. ACAS X has the flexibility to reduce unnecessary alerts, support use of alternative surveillance sources, enable Future Generation Air Transportation Sytem (NextGen) and potentially provide a collision avoidance capability for new user classes.

With satellite-based NextGen technologies, aircraft are tracked with a higher precision than with radar and safe separation distances may be reduced. This means that aircraft can get through busy airspace more efficiently.

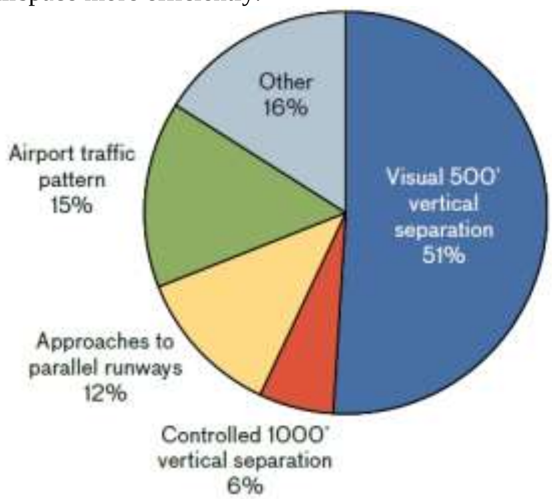

Fig. 1. Observed TCAS RAs events in the United States. Most advisories are issued during normal and safe operation [1]

Instead of using a set of hard-coded rules, ACAS X threat logic takes advantage of logic table optimized with respect to a probabilistic model of the airspace and Plug-and-Play Surveillance. Probabilistic models provides sensor model, dynamic model and in addition multi-objective utility model. Probabilistic sensor model gives information lead to uncertainty in position and velocity of aircraft, which is defined as a State Uncertainty.

Fig. 2. Step 1: State Distribution. Estimate ~10M states based on beliefs about own and intruder dynamics.[3]

Dynamic Uncertainty (Probabilistic dynamic model) is determined as a variability in pilot behavior which makes it difficult to predict future trajectories of aircraft.

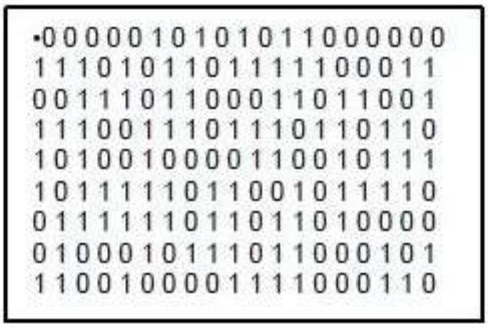

Fig. 1. Step 2: Look-Up Table. For each state estimation, look up expected cost related to available actions.[3]

Multiple objectives defined system that carefully balance both safety and operational consideration. Various models are used to estimate a state distribution, which is probability distribution over the current positions and velocities of the aircraft. The distribution state determines where to look in the numeric lookup table to establish expected cost of related to available actions for each state. This is introduced into an optimization process called dynamic programming to define the best solution of action to follow according to the context of the conflict.

No Alert	0.8
Level-off	0.1
Descend	0.9
Climb	0.2

Fig. 4. Step 3: Choose action with lowest cost.[3]

ACAS X Variants:

- ACAS Xa (**A**ctive Surveollance) – The general purpose ACAS X which provides global protection against tracked aircraft and establish the range of intruders. ACAS Xa is the baseline system intended for current TCAS II users (large aircraft).
- ACAS Xo (**O**peration Specific) – designed for users of specific operations for which ACAS Xa may generate the large amount of nuisance alerts (e.g. CSPO, Formation Flights, ASAS Operations).
- ACAS Xu (**U**nmanned aircraft) – is optimized for unmanned aircraft systems (UAS).
- ACAS Xp (**P**assive) – A version of ACAS X that is based solely on passive tracks threats for low-performance general aviation aircraft that are not currently required to fit TCAS II).

IV. ACAS XA

It is assumed that ACAS Xa will provide an improvement in safety while has the potential to dramatically decrease unnecessary alerts by one third and cut collision risk in half. The version of ACAS X intended for use for large aircraft will use the same co-ordination mechanism and the same hardware (antennas and displays) as TCAS II. Additionally, the same range of RAs will be used as in TCAS II version 7.1. This should guarantee interoperability between these two systems. It is the intention that ACAS X will eventually replace TCAS II.[8]

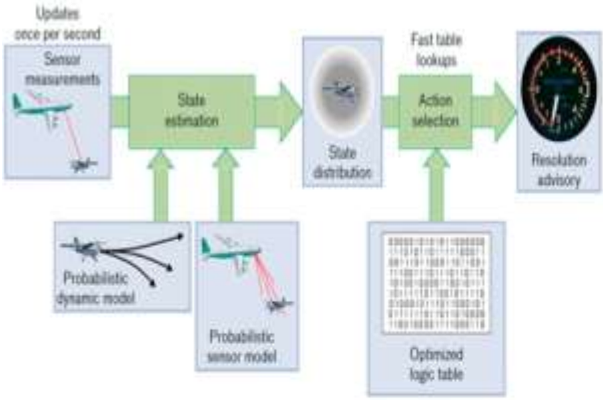

Fig. 5 ACAS X processing chain [6]

Major differences between TCAS II version 7.1 and the concept for ACAS Xa are the sources of surveillance data and collision avoidance logic.

TCAS II used in the majority of commercial aviation aircraft relies on interrogation signal which is sent from the TCAS unit and the time is measured unit a response is received from the transponders of other aircraft. One a serious threat is detected, the TCAS II computer will automatically establish a link with the TCAS II computer on the other aeroplane. The computer will "agree" and co-ordinate optimum avoidance maneuver and Resolution Advisories (RAs) instructions will be announced on the appropriate TCAS II display in each of the involved aircraft. Currently, the avoidance maneuvers are restricted to changes in altitude (climb or descent), and to modifications of climb/descent rates.

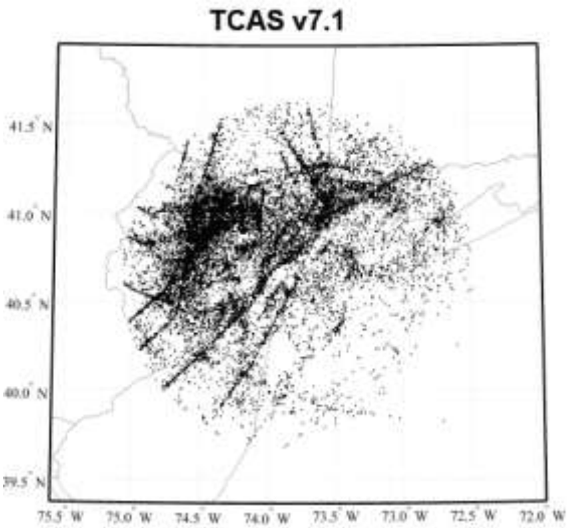

Fig. 6 TCAS version 7.1 amount of alerts taken over a multiyear period of time in JFK region.[2]

ACAS X will provide the same general role as TCAS II which consist of surveillance of nearby aircraft, TA/RA generation and coordination with other aircraft collision avoidance systems but support new capabilities. Among these new features, we can distinguish usage of additional surveillance sources, an extension for multiple types of host aircraft and adaption for Reduced Separation Operations.

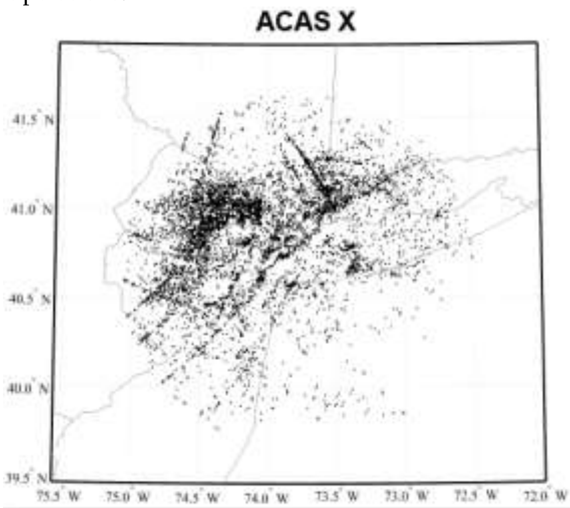

Fig. 7. ACAS X amount of alerts based on simulations of system over multiyear period of time in JFK region. [2]

V. BENEFITS OF ACAS X

ACAS X is expected to deliver several improvements and provides more operational suitability than does TCAS II. In addition to protecting the traveling public on board, the following benefits are foreseen through the introduction of ACAS X:

- Minimize the amount of 'unnecessary' advisories to normal air traffic flow. TCAS II is an effective system, but it can issue alerts in situations where aircraft will remain safely separated.
- Adapt to future operational concepts: SESAR and NextGen. Implementation of new operational concepts will reduce the spacing between aircraft. ACAS X accommodate new surveillance inputs which provide more precise tracking data than do the currently used transponders.
- Extend collision avoidance to other classes of aircraft. To ensure alerts can be followed, TCAS II is restricted to categories of aircraft capable of achieving specified performance criteria (e.g. aircraft must be able to achieve a rate of climb of 2500 ft/min) which excludes many General Aviation and Unmanned Aircraft Systems.
- Contribute to reduce fuel costs, emissions and flight operating times, as well as increased arrival rates at airports.
- Reduce collision risk and improve safety. Initial results from conducted flight tests with an ACAS X prototype show that ACAS X has the potential to dramatically decrease unnecessary alerts by 30 percent and cut collision risk by 50 percent.

- System updates. The numeric look-up table adopted by ACAS X is expected to facilitate easier and with lower costs, by reducing the need for maintenance heavy hardware upgrades.

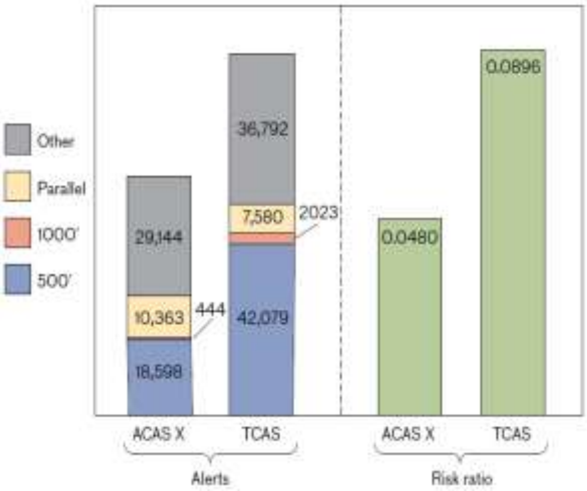

Fig. 7. Comparison of ACAS X and TCAS in relation to amount of unnecessary alerts with risk ratio. [1]

VI. Conclusions

ACAS X has reached a state of sufficient maturity that industry and international participation in development activities will facilitate acceleration of fielding a future collision avoidance capability. While work continues to optimize and fine-tune the system, a Federal Advisory Committee will begin to develop minimum performance standard for ACAS X. In 2013, FAA has successfully conducted proof-of-concept flight tests of ACAS Xa prototype using more than 120 scenarios. The standards are expected to be formalized in 2018 [7] with flight evaluation to follow the next year. ACAS X is scheduled to be fully operational around 2020.[4]

It is expected that ACAS Xa will subsequently be installed in more than 30,000 transport-category passenger and cargo aircraft worldwide.

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