Contextual note – SESAR Solution description form for deployment planning
PJ.11-A1: ACAS Xa European acceptability framework

Purpose:

This contextual note introduces a SESAR Solution (for which maturity has been assessed as sufficient to support a decision for industrialization) with a summary of the results stemming from R&D activities contributing to deliver it. It provides to any interested reader (external and internal to the SESAR programme) an introduction to the SESAR Solution in terms of scope, main operational and performance benefits, relevant system impacts as well as additional activities to be conducted during the industrialization phase or as part of deployment. This contextual note complements the technical data pack comprising the SESAR deliverables required for further industrialization/deployment.

Improvements in Air Traffic Management (ATM)

Solution PJ.11-A1 covers the development and use of a framework to assess European acceptability of ACAS Xa in Europe. ACAS Xa is the variant of the ACAS X concept for Commercial Air Transport normal operations. ACAS X is an FAA currently-under-development new family of collision avoidance systems. ACAS Xa is an aircraft collision avoidance system being designed with the intent to be proposed as the next generation of ACAS II system with general voluntary equipage beginning in the 2020-2023 timeframe. The targeted fleet is the set of aircraft that are subject to the current ACAS II mandate, i.e. those with a minimum take-off weight of 5.7 t and/or at least 20 passenger seats.

ACAS Xa improves on current Airborne Collision Avoidance for Commercial Air Traffic by taking advantage of additional surveillance data and of mathematically optimised resolution advisories, without changing the cockpit interface (same alerts and presentation).

Currently, collision avoidance alerts are based on a unique surveillance source (active Mode C/S interrogations). ACAS Xa uses information from the more accurate surveillance source available between the classic active source and an additional passive source, ADS-B surveillance data. In addition, the data from the surveillance sources are processed by state-of-the-art trackers which increases the reliability of the track.

Currently, collision avoidance alerts are based on a series of empirical rules. ACAS Xa optimises the rules for triggering an RA by applying state-of-the-art mathematical processes and modelling.

In current operations ACAS Xa is expected to improve significantly both safety (avoiding more NMACs) and operational compatibility (less unwanted RAs). In addition, ACAS Xa introduced a new CAS logic development method allowing for faster cycles of development and easier maintenance of the documentation. The method will facilitate the development of new ACAS for other classes of aircraft (RPAS and GA/RC) as well as for specific operations (such as some future operations) where standard ACAS Xa may produce unwanted RAs.

As an airborne collision avoidance system, ACAS Xa will bring benefits when operated in all airspaces, whether TMA or En-route, controlled or uncontrolled, providing protection against collision with cooperative aircraft (Mode C/S or ADS-B out).

Operational Improvement Steps (OIs) & Enablers

The applicable Integrated Roadmap Dataset is DS19:

- CM-0808-a: Improved Collision Avoidance for commercial air transport in standard operations (ACAS Xa) – Full coverage by the solution
- A/C-54a: Enhanced Airborne Collision Avoidance (ACAS) – Partial coverage by the solution

A set of CRs have been endorsed for the next DS in order to rescope A/C-54a which covers too much ground for CM-0808-a. CM-0808-a will also have a predecessor covering the reduction of RF spectrum use by airborne surveillance systems, enabled by extended hybrid surveillance, which was validated in technological solution #101.

These CRs are:

CR 03547 *Update A/C-54a (PJ.11-A1)*
CR 03548 *Update CM-0808-a with link to CM-0808-o*
CR 03756 *Create POI-0036-SUR for Solution #101*
CR 03757 *Create A/C-54a0 for Solution #101*

Background and validation process

In order to assess ACAS Xa, the solution setup a European acceptability framework. Its underlying methodology is the encounter model methodology. It is a powerful technique by which a very large set of encounters can be stochastically generated to assess the benefits of safety nets. This technique is appropriate in the case of safety nets because ACAS alerts are rare events. Fast-time simulations using encounter sets produced by encounter models allow to simulate ACAS Xa Run 15 logic on the equivalent of several years of radar data.

The key elements of the European acceptability framework are:

- encounter models, which are a mathematical model of traffic situations involving two aircraft that captures the properties of encounters captured from radar data. Two types of encounters models were setup:
    - safety encounters model, for which the captured encounters are those in which two aircraft are on a close encounter course, typically within 500 ft horizontally at closest approach. They are used to assess safety. The solution used a previous general safety model (AVAL), a specialized safety model for Uberlingen geometries (SA01) and a newly developed general safety model (CREME-S);
    - a safety-net related encounter model, for which the captured encounters are those with broader horizontal separation, but still close enough to present a potential for an safety-net alert (either ACAS or STCA). It is used to assess operational compatibility with ATC and pilot confidence. The solution used a previous general safety-net related model (PASS);
- simulation software implementing the new ACAS logic, with interfaces that were developed specifically. It is used to run any ACAS logic on the encounters from the encounter models and produce modified encounters taking into account the effect of any alert (responding to it according to a pilot response model);

- pilot models. A standard pilot model can be used to reflect the response to RAs as expected by the ACAS system. A typical pilot model exists which reflects a broader range of pilot responses as observed in reality;

- altimetry error models. Below RVSM airspace, an ICAO altimetry error model is used while in the RVSM airspace, a specific model has been designed;

- a set of indicators defined in SESAR document 4.8.1-D101, covering safety and operational compatibility, classified in two tiers of importance, with a rationale and a proposed acceptability threshold.

As the ACAS Xa is developed by FAA, the SESAR contribution consisted in a validation of the European performance of ACAS Xa. ACAS Xa development was incremental and therefore the validation covered several successive iterations, called Runs.

ACAS Xa is made up of a module ensuring the surveillance of the surrounding traffic, the STM (Surveillance and Tracking Module) and of a module determining if an advisory is needed and which one, the TRM (Threat Resolution Module). The validation addressed those modules both separately and in combination.

Overall, the validation path to mature ACAS Xa to V2 and then V3 spanned 17 fast-time simulations and 1 real-time simulation. The high level summary of these activities is presented hereafter:

- For the STM, five fast-time simulations were performed. Using airborne data recorded in flight tests of Extended Hybrid Surveillance (solution #101) and ground data recorded in Toulouse, they investigated the efficiency of internal STM trackers in providing more accurate values than the sensor-provided data, the probability of ADS-B validation failure, the sensitivity of the STM performance to varying input data quality and the influence of data quality on one parameter output by the STM which is essential to the TRM. The simulations addressed Runs 13, 14 and 15.

- For the TRM, eleven fast-time simulations were performed. Using data sets mainly generated by several encounter models but also some recorded European radar data, they investigated the TRM performance (assuming perfect knowledge of intruder positions and only active surveillance) in terms of safety, compatibility with ATC methods and acceptability by flight crews, compared to the performance of the current system, TCAS II v7.1. The compatibility with the SESAR 1 TCAP feature (solution #105) was also looked at.

  The analysis sought to determine if a good result in an indicator did not hide an issue for some classes of encounters but also to analyse the mechanism by which concerning situations occur and possible ways to mitigate or correct the behaviour.

  The simulations addressed Runs 11, 12 (with the full range of indicators), 13, 14 and 15 (with a partial range of indicators due to an unexpected number of sub-versions being issued by FAA).

- For the whole system (STM+TRM):

  - One fast-time simulation was performed, after the first series of three fast-time simulations conducted on the Run 13 STM. The system under test was an integrated model of Run 13 STM and TRM with a capability to add noise to the input positions. Only data sets from encounter models were used. The investigation computed the

main safety and operational suitability indicators as done for TRM, with different scenarios of input noise.

- One real-time simulation was performed. It consisted in getting the feedback of airline and flight test pilots on the suitability of ACAS Xa RAs based on a series of 12 such RAs produced during “nominal situations” (for ACAS encounters) along a flight from Paris to London and back. The simulation addressed Run 14.

No flight trials were performed in Europe. In the scope of SESAR, one member of the solution team contributed to the setup and analysis of a flight trial that was organised by FAA on Run 13.

Results and performance achievements

The main findings from the overall validation exercises are the following:

- Based on Run 15.3 STM, the accuracy of the tracked values is better than the accuracy of the input surveillance data. Although trackers are still overconfident in estimating the confidence area of the intruder position sample that it provides to the collision avoidance logic, the whole system is not affected as the TRM is tuned taking into account this accuracy;
- Based on Run 14 STM and TRM, the level of operational acceptability of ACAS Xa in the European environment from a pilot’s perspective is satisfactory, except in one use case where the RA was considered as too late;
- Based on Run 15.4 TRM, the following benefits have been identified:
  - Safety is improved in a theoretical environment with 100% ACAS Xa fleet by 16% on the overall European airspace
  - Compatibility with ATC is improved: 90% reduction on 1,000ft Single Level-Off encounters
  - The benefits are obtained gradually during the transition period from a full TCAS fleet to a full ACAS Xa fleet

  But the following areas of concern for Europe have been identified:
  - Slight degradation (1%) in Risk Ratio observed above FL135 with ACAS Xa (against unequipped intruders) due to head-on encounters with the unequipped aircraft crossing the level of the equipped aircraft with a vertical speed greater than 4,000 ft
  - Twice more cases of very close encounters without corrective RAs
  - Possibility to trigger unusual types of RA sequences with ACAS Xa: Reverse Crossing RAs and triple Reverse RAs, which will be stressful for pilots and may not be complied with
  - More Increase RAs, Crossing RAs, complex RA sequences, which means that the benefits of ACAS Xa are more dependent than TCAS on the flight crew faithful compliance
  - XMore alerts when aircraft with a vertical speed slower than 1,500 fpm are levelling-off 1,000 ft below or above another aircraft.

- Lack of weakening RAs with ACAS Xa leading to high vertical deviations (quid of the risk of encountering a third aircraft?)
- Lack of preventive RAs in situations where two level aircraft cross each other 500 ft apart.

The concerns listed above have forwarded to FAA and will be taken into account by EASA to decide on the acceptability of ACAS Xa in the European airspace/

- Based on Run 15.4 TRM, not only TCAP has been shown to be compatible with ACAS Xa, but the study has shown that TCAP permits to obtain even more operational benefits when combined with ACAS Xa than when combined with TCAS II. This means that airlines adding TCAP to an ACAS Xa equipped aircraft or moving from TCAS to ACAS Xa on a TCAP aircraft would see a significant reduction of operationally undesired RAs.
- From a CBA point of view, two scenarios were studied: one with just a forward fit and another with a mandated retrofit. The forward fit scenario is the one describing the currently expected path for ACAS Xa deployment. In this scenario, the cost of deployment is high (but spread over two or three decades) for airlines and limited for the ANSPs. The benefits could not be quantified.

Recommendations and Additional activities

The following activities are relevant in order to prepare for the deployment of ACAS Xa:

- Update of ground systems downlinking RA data. ACAS Xa downlink format is different from TCAS II v7.1 downlink format, so ANSPs that collect ACAS data by requesting or listening to RA reports need to adapt their systems;
- Update of tools used by incident / accident investigators. ACAS Xa decision making is different from TCAS II v7.1 decision making. Incident / accident analysis tools must be able to show specific ACAS Xa parameters that are used in the decision making each second throughout the encounter;
- Training of pilots. It is not essential as the procedure and the interfaces are unchanged but would be helpful for a smooth transition.
- Training of controllers. It is not essential as the procedure is not changed but would be helpful for a smooth transition.
- Training of incident / accident investigators. They should be knowledgeable about how ACAS Xa decides to trigger alerts and they should be trained on the updated analysis tool.

Actors impacted by the SESAR Solution

Pilots of equipped aircraft and executive controllers will have to receive training to be aware that ACAS Xa advisory occurrence, timing and strength may be different from their experience with TCAS. Pilots will have to adapt to this change so that they do not second-guess the reactions of the system. The benefit of less nuisance RAs may not be perceived by pilots and controllers as the transition from TCAS to ACAS Xa may be very slow.

Incident/accident investigators will have to receive training to be able to analyse encounters in which at least one of the aircraft is ACAS Xa equipped.

Impact on Aircraft System

ACAS Xa is an airborne system which is designed to be a replacement for TCAS II v7.1. Therefore, no change to the avionics is necessary to install ACAS Xa.

Impact on Ground Systems

Ground systems used to collect information on ACAS RAs triggered in the airspace, whether for displaying them in real-time on controllers' working positions or for investigating incidents or accidents, will have to be updated to take into account messages / reports sent by ACAS Xa.

Regulatory Framework Considerations

ACAS Xa MOPS (RTCA DO-385 / EUROCAE ED-256) have been published in October 2018. They are the basis for FAA regulation and referred in TSO-C219 which is currently circulated for comments. EASA will have to decide if ACAS Xa Run 15.4 is acceptable in Europe, based on the above mentioned rerun of the Run 15.4 verification. If it is acceptable, then EASA will have to act to modify Commission Regulation 1332/2011, amended by Commission Regulation 2016/583, which specifically mentions version 7.1 as the mandated software for airborne collision avoidance.

Standardization Framework Considerations

ACAS Xa MOPS (RTCA DO-385 / EUROCAE ED-256) have been published in October 2018. They include requirements to ensure interoperability with current ACAS but also with future ACAS and DAA systems. In this respect, they are compliant with the upcoming RTCA/EUROCAE interoperability MASPS. ACAS Xa MOPS also incorporate extended hybrid surveillance and hybrid surveillance provisions that are compliant with RTCA DO-300A Change 1 / EUROCAE ED-221A.

A modification of ICAO Annex 10 volume IV to take into account ACAS Xa specificities and confer him the "ACAS II" label (as TCAS II v7.1) has been drafted and is awaiting ICAO ANC approval. The result will be that ACAS Xa can be accepted worldwide as a means to fulfil the ICAO ACAS II mandate, in the same way as TCAS II v7.1

Considerations of Regulatory Oversight and Certification Activities

The Regulatory Oversight and Certification Activities can be carried over from what is already done for TCAS II. A main difference with TCAS is that particular attention should be paid that the ACAS Xa common software elements which are delivered by RTCA (table + parameters) have not been corrupted before being uploaded in the ACAS Xa unit.

Solution Data pack

The Data pack for this Solution includes the following documents:

- **VALR** – PJ11-A1 D3.1.060, Edition 00.01.01 (19/07/2019)

This document provides the results of the four V3 validation exercises, consolidates them in order to conclude on the V3 maturity of the solution and provide recommendations for the next steps.

- **TS** – PJ11-A1 D3.1.040, Edition 00.01.01 (03/10/2019)

  This document summarizes an up-to-date status of ACAS X surveillance requirements, definitions, and assumptions, together with a list of any identified open points and gaps. Since ACAS Xa technical specifications are well documented in recently published ACAS Xa/Xo MOPS, this document mostly serves for proper definition and setting of the ACAS Xa into SESAR European ATM Architecture.

- **CBA** – PJ11-A1 D3.1.050 Edition 00.01.01 (03/10/2019).

  This V3 CBA estimates costs and provides evidence on the benefits of a potential deployment of the Solution PJ11-A1 across ECAC. The safety benefits of the solution are assessed in terms of proportion of NMACs avoided. The costs include the Airspace Users cost of equipping their fleet but also some minor ANSP costs.

Intellectual Property Rights (foreground)

The foreground is owned by the SJU.