Enhanced Air and Ground Safety Nets Final Project Report

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(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

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00.00.02	28/10/2018	Draft	Jamal Chehade Bill Booth David Castellano Ramírez Christian Aveneau Petr Casek Pavel Klang Silvie Luisa Brazdilova	Document initiation
00.01.02	31/10/2019	Final	Jamal Chehade	Final version
00.01.03	16/12/2019	Final	Jamal Chehade Bill Booth David Castellano Ramírez Christian Aveneau Petr Casek Pavel Klang Silvie Luisa Brazdilova	Update according to the SJU comments : all the section : - Content reduction - Removing programmatic information
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Xa European Acceptability Framework.

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[CAPITO]

[ENHANCED AIR AND GROUND SAFETY NETS]

This Final Project Report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No [732996] under European Union's Horizon 2020 research and innovation programme.

Abstract

This document represents the Final Project Report of the project "Enhanced Air and Ground Safety Net" – CAPITO - project. It describes the work performed during the time period 01/11/2016 – 31/12/2019 to mature the solutions:

- The Solution **Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information** has achieved V2 Maturity level
- The Solution **ACAS Xa European Acceptability Framework** has achieved V3 maturity level
- The Solution **Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu** has achieved V2 Maturity level
- The Solution **ACAS for Commercial Air Transport specific operations – ACAS Xo** has progressed in V1 Maturity level
- The Solution **Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+** has achieved V2 Maturity level.

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

Table of Contents

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List of Tables

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List of Figures

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Executive Summary

The project is concerned with Enhanced Air and Ground Safety Nets. It is comprised of five solutions: one ground based and four airborne solutions.

- The solution **Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information** contributes to an improved Short Term Conflict Alert and None Transgression Zone ground based safety nets in different operational environments by increasing the effectiveness on alert declaration, positive impact on safety, positive impact on human performance and increasing the trust of the controllers in the system.

  This solution achieved V2 maturity level;

- The solution **ACAS Xa European Acceptability Framework(*)** validates the introduction of ACAS Xa in Europe. Ensure that flight crew confidence in the collision avoidance system (and thus a good manual response to the alerts) is maintained; and analyses the interaction of ACAS Xa with specific European aircraft features developed in SESAR 1.

  This solution achieved V3 maturity level;

- The solution **Airborne Collision Avoidance for Remotely Piloted Aircraft Systems (ACAS Xu)** Supports the integration and safe use of commercial Remotely-Piloted Aircraft Systems (RPAS) into ATM through the development of RPAS-dedicated variant of Airborne Collision Avoidance System – so-called ACAS Xu.

  This solution achieved V2 maturity level;

- The solution **ACAS for Commercial Air Transport specific operations (ACAS Xo)** Identifies the main use cases for ACAS Xo capability within current and future European operations; evaluates the benefits/suitability of the basic ACAS Xo implementation developed by FAA for these European scenarios; evaluates the opportunity in terms of achievable benefits for a tailored ACAS Xo implementation addressing selected use cases and defines the relevant technical and operational requirements.

  This solution validated the technical feasibility and pilot's acceptability of ACAS Xo. Additional work is needed to reach the V2 maturity level and this solution is still at V1 (ongoing);

- The solution **Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems (TSAA+)** Evaluates the operational and safety benefits achievable by an extension of Traffic Situation Awareness with Alerts (TSAA+) during mixed equipage encounters and refine validation of operational benefits of TSAA in European airspace.

  This solution achieved V2 maturity level.

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

1 Project Overview

The project is concerned with Enhanced Air and Ground Safety Nets. Airborne Collision Avoidance Systems (ACAS) are operational globally and need to be optimised for all airspace and are required to be compatible with existing systems. The scope of work is extended from that performed within SESAR1 to include Remotely Piloted Aircraft Systems (RPAS), General Aviation (GA), rotorcrafts (R) and military operations. Accommodating RPAS integration safely is a prerequisite for the development of the RPAS business.

1.1 Operational/Technical Context

Collision Avoidance forms the last element in the ATM safety chain (see below) where Separation has been compromised

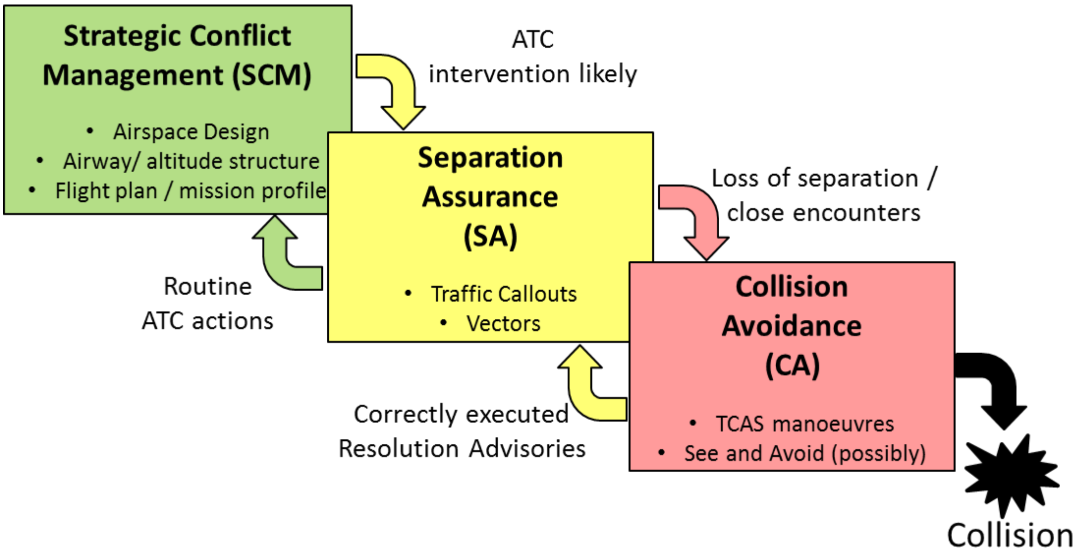

Figure 1: ATM Safety Layers

The current Safety Net layer consists of Airborne Collision Avoidance (ACAS) and Ground Based Safety Net (STCA).

1.2 Project Scope and Objectives

This project addresses the operational and technical objectives of the Enhanced Air & Ground Safety Nets defined in the SESAR 2020 Multi Annual Work Program.

It is comprised of five solutions: one ground related solution and four air-related solutions.

The main objectives as defined by the Solutions:

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- Solution **Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information:**

  contributing to an improved Short Term Conflict Alert and None Transgression Zone ground based safety nets in different operational environments by increasing the effectiveness on alert declaration, positive impact on safety, positive impact on human performance and increasing the trust of the controllers in the system.

  Improves the Short Term Conflict Alert (STCA) via system support to the Non Transgression Zone (NTZ) safety NET including the use of downlinked aircraft parameters (DAPs); develop a minimum STCA and NTZ Operational, Safety and Performance Requirements.

- Solution **ACAS Xa European Acceptability Framework:**

  Validate the introduction of ACAS Xa in Europe. Check that flight crew confidence in the collision avoidance system (and thus a good manual response to the alerts) is maintained; analyses the interaction of ACAS Xa with specific European aircraft features developed in SESAR 1.

- Solution **Airborne Collision Avoidance for Remotely Piloted Aircraft Systems (ACAS Xu)**:

  Support the integration and safe use of commercial Remotely-Piloted Aircraft Systems (RPAS) into ATM through development of RPAS-dedicated variant of Airborne Collision Avoidance System – so-called ACAS Xu. Operational scope of PJ.11-A2 is focused on IFR operations within the airspaces A-C where separation management is handled for RPAS by Air Traffic Control (ATC) in the same or similar way as for manned aviation. The primary technical goal is to contribute to development of ACAS Xu in the way that the final standardized system addresses correctly the European operational and technical needs. This is done primarily through progressive evaluations of ACAS Xu development versions (so-called Runs) within European scenarios/encounters models, and through development of European acceptability criteria for ACAS Xu.

- solution **ACAS for Commercial Air Transport specific operations (ACAS Xo):**

  Identify the main use cases for ACAS Xo capability within current and future European operations; evaluate the benefits/suitability of the basic ACAS Xo implementation developed by FAA for these European scenarios; evaluate the opportunity in terms of achievable benefits for a tailored ACAS Xo implementation addressing selected use cases and define the relevant technical and operational requirements.

- Solution **Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems (TSAA+):**

  Evaluate the operational and safety benefits achievable by TSAA+ during mixed equipage encounters and refine validation of operational benefits of TSAA in European airspace.

1.3 Work Performed

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

1.3.1 Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information

The high-level approach of this validation was to perform a set of exercises to prove whether STCA and NTZ ground-based safety nets, improved by means of Downlink Aircraft Parameters transmitted via ADS-B and Mode-S, obtain a better performance in terms of optimum alerting time and reduction of nuisance alerts. This solution reached V2 maturity level at the end of this project.

For this validation, the following set of exercises were executed:

- Improved STCA using DAPs via ADS-B and Mode-S for vertical (level off) manoeuvres
- Improved STCA using DAPs via ADS-B and Mode-S for horizontal (turn) manoeuvres.
- Implement the NTZ safety net using DAPs via ADS-B and Mode-S for independent parallel runways approach

A set of documents (VALP, VALR, SPR-INTEROP/OSED, TS, CBA) have been performed to support the final deliverable D2.1 of the V2 DataPack.

1.3.2 Solution ACAS Xa European Acceptability Framework

The work built on what was already done in SESAR 1 to bring the solution (ACAS Xa system) from V1 to V2. It had to take into account several sub-versions of the final ACAS Xa version, Run 15.

This was done through 4 exercises, mainly with fast-time simulations on encounter sets from European encounter models, but also on a prototype for the first exercise. Metrics related to surveillance accuracy, safety and operational compatibility were computed.

- Performance of Run 15 STM and sensitivity to surveillance errors
- Safety and operational acceptability of Run 15 collision avoidance logic
- Run 15 TRM compatibility with TCAP
- Verification of ACAS Xa released version suitability for European airspace. This exercise was performed twice to remove some uncertainties.

The results obtained for the surveillance performance as well as the standards drafted by RTCA/EUROCAE informed the Technical Specifications (D3.1.040). All along the project lifetime, coordination with the US teams took place to highlight possible improvements and the project team participated to the solution standardization taking place in RTCA / EUROCAE.

A set of documents (VALP, VALR, TS, CBA) have been performed to support the final deliverable D3.1 V3 DataPack.

1.3.3 Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

The PJ.11-A2 solution builds on the outcomes of ACAS Xa work (SESAR 1 Projects 9.47 and 4.8.1, and SESAR 2020 ATM Solution ACAS Xa European Acceptability Framework). A reference implementation of ACAS Xu is developed by MIT within FAA ACAS X program and released in the form of so-called "Runs". This solution performed progressive independent evaluations of ACAS Xu using European scenarios/encounter models and communicated findings to FAA/MIT in order for these to be taken into account for ACAS Xu evolution.

Within the V1 phase, the validation activities focused on initial analysis of the new (when compared to ACAS Xa) functional elements of ACAS Xu. Run 3 of ACAS Xu (released in 2017) was used for this purpose with attention given primarily on horizontal maneuvering, with the Nucleus logic selecting whether vertical or horizontal collision avoidance will be used

Compared to the V1 phase, the V2 validation activities addressed a broader scope with three complementary exercises evaluating separately logic, surveillance and interoperability characteristics. More advanced encounter-models/scenarios were used and the exercises evaluated more mature Runs. The V2 phase thus represents additional progressive steps towards mature and standardized ACAS Xu system targeted, according FAA program schedule, at the end of 2020 (for MOPS Standards).

Beyond the validation activities, the initial version of European acceptability criteria for ACAS Xu were developed and included as an annex to the OSED. These criteria are more complex than those developed for ACAS Xa and is something to be developed in SESAR Wave 2.

A set of documents (VALP, VALR, SPR-INTEROP/OSED, TS, CBA) have been performed to support the final deliverables D4.1 V1 DataPack and D4.2 V2 DataPack.

1.3.4 Solution ACAS for Commercial Air Transport specific operations – ACAS Xo

The validation approach for ACAS Xo solution for V2 was defined in the Validation Plan (D5.1.010) and consists of two validation exercises for the ACAS Xo solution:

- **Stakeholder Workshop** focused mainly on the ACAS Xo operational procedures. A low fidelity digital mock-up of ACAS Xo HMI was developed and presented to the participants to help them define and validate the operating method.
- **Real Time Simulation (RTS)** was performed on integration simulators with ACAS Xo prototype developed by this project (Availability Note D.1.030). The purpose of RTS was to assess and validate principles for intruder designation, alert triggering, and associated Human Machine Interface.

From technical point of view, no technical blocking point towards V2 was observed. The ACAS Xo system was standardized by both EUROCAE and RTCA and the MOPS document ED-256/DO-385 was published in October 2018.

A set of documents (VALP, VALR, SPR-INTEROP/OSED, TS, CBA) have been performed to support the final deliverable V2 DataPack.

1.3.5 Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

The original focus of the project was ACAS Xp (a version of ACAS X relying solely on passive ADS-B information). However, the scope of the project was changed to TSAA+ after the V1 maturity gate.

This solution reached V2 maturity level.

The following validation exercises were performed:

- Human Performance assessment (workshop with pilots in a simulator using an experimental mock-up display and artificial scenarios).
- Probability of Near Mid-Air Collision comparison and rate change & reversal ratio comparison (both TSAA vs. TSAA+). These experiments were fast time simulations on selected real European encounters.
- Refinement of TSAA alerting performance, i.e. estimation of missed and outlying alerts. This experiment was also fast time simulations on real European encounters.

In addition, two exercises on ACAS Xu usability for GA/R/St and interoperability that were planned before the project scope change.

A set of documents (VALP, VALR, SPR-INTEROP/OSED, TS, CBA) have been performed to support the final deliverable D6.1 V1 DataPack and D6.2 V2 DataPack.

1.4 Key Project Results

1.4.1 Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information

The solution has achieved V2 maturity level and it is characterized by a V2 set of matured requirements contained in the deliverables of the DataPack.

The validation performed for this solution, provided the following key results :

- Anticipation in the declaration alert time in the detection of imminent or actual losses of separation
- Reduction of the number of STCA nuisance alerts
- Reduction of the number of situations derived on Imminent Collision
- Anticipation in the declaration alert time in the detection of imminent or actual transgressions situations
- Reduction of the number of NTZ nuisance alerts
- Reduction of the number of situations derived on Imminent Transgression

This set of results is contained in the Validation Report (D2.1.060) and a list of recommendations is included in the Validation Plan for the next step.

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1.4.2 Solution ACAS Xa European Acceptability Framework

The solution has achieved V3 maturity level and it is characterized by a V3 set of matured requirements contained in the deliverables of the DataPack and RTCA / EUROCAE MOPS.

The key results are the following;

- Surveillance accuracy improved from the previous ACAS Xa version but did not fully satisfy the target set by the project. However, this should be OK as the TRM is tuned taking into account this accuracy.

- Overall risk ratio is improved but the gains are obtained using more often stressful RAs than TCAS II (crossing and/or reverse and/or complex sequence) and thus are more dependent on good pilot compliance with the RAs. Two safety issues are still there: a lack of corrective RAs in very close encounters and a slight safety degradation over FL135.

- Flight crews and controllers will be less disturbed by unnecessary alerts but vertical deviations from the CFL will be higher with ACAS Xa than with TCAS. In addition, ACAS Xa alerts more than TCAS when aircraft with a vertical speed slower than 1,500 fpm are levelling-off 1,000 ft below or above another aircraft.

- TCAP is fully compatible with ACAS Xa and would provide significant benefits to aircraft equipped with ACAS Xa.

Although the solution has been proven technically mature at a V3 level.

From a CBA point of view, the cost of deployment is very high (but is expected to be spread over two or three decades), and the benefits (less accidents) are only in TMA.

1.4.3 Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu

The solution has achieved a V2 maturity level and it is characterized by a V2 set of matured requirements contained in the deliverables of the DataPack..

Results of the V1 fast time simulations showed that under nominal conditions (and assuming timely reaction to alert), ACAS Xu Run 3 correctly prevented Near Mid-Air Collision (NMAC) in all simulated collision scenarios.

Within the V2 phase these results were further extended for a more mature version of ACAS Xu and using larger and more complete encounters sets. Additionally in this case the Risk Ratio indicates a safety improvement of the ACAS Xu logic whether it is compared to a non-equipped encounter, a TCAS II or ACAS Xa manned aircraft.

V1 results indicated an extensive use of horizontal manoeuvring by Run 3 and, in general, a considerable impact of the type of surveillance used on the ACAS Xu performance. A considerable impact of surveillance was visible also in V2 results but without any safety degradation identified for nominal (required) noise level. The use of horizontal manoeuvring was considerably improved in Runs 4.x.

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Both V1 and V2 results showed that ACAS Xu alerts earlier than TCAS II or ACAS Xa during mixed-equipped encounters. At the same time, ACAS Xu seems to be able to solve more encounters alone compared to Xa-Xa encounters and thus reduce the number of manoeuvring aircraft. On the other hand, earlier alerts could be potentially disruptive to ATC, and therefore these two opposite effects should be further explored when evaluating operational acceptability in V3.

This set of results is contained in the Validation Report (D4.2.030) and a list of recommendations is included in the Validation Plan for the next step.

1.4.4 Solution ACAS for Commercial Air Transport specific operations – ACAS Xo

The solution status is still V1 ongoing. The technical feasibility and pilot's acceptability of ACAS Xo were validated. But a new operational concept needs to be defined with focus on agreement between pilots and ATC defining the procedure by which pilots identify and designate the right aircraft for correct ACAS Xo mode.

This set of results is contained in the Validation Report (D5.1.060) and a list of recommendations is included in the Validation Plan for the next step.

1.4.5 Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+

The solution has achieved V2 maturity level from both technical and conceptual points of view.

The concept was validated through a set of exercises where the safety benefits were clearly proven. Specifically, a considerable in reduction of compromising ACAS RA was achieved. The probability of near mid-air collision with TSAA+ is lower than with TSAA. The TSAA itself was re-evaluated with positive results in terms of alerting performance (missed and outlying alerts). Although a mock-up prototype HMI was used for human performance assessment, the overall acceptability by the users is positive.

This set of results is contained in the Validation Report (D6.2.040) and a list of recommendations is included in the Validation Plan for the next step.

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1.5 Technical Deliverables

1.5.1 Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information

Reference	Title	Delivery Date[1]	Dissemination Level[2]
Description			
D2.1	Solution PJ11-G1 V2 Data Pack	30/07/2019	PU
This Documents contains the OSED (SPR-INTEROP-OSED, the Validation Report (VALR), the Technical Specifications (TS-IRS) and the Cost Benefit Analysis Report(CBA).			

Table 1: Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information Deliverables

1.5.2 Solution ACAS Xa European Acceptability Framework

Reference	Title	Delivery Date[3]	Dissemination Level[4]
Description			
D3.1	Solution PJ11-A1 V3 DataPack	05/06/2019	CO
This Documents contains the Validation Report (VALR), the Technical Specifications (TS-IRS) and the Cost Benefit Analysis Report(CBA).			

Table 2: Solution ACAS Xa European Acceptability Framework Deliverables

[1] Delivery data of latest edition

[2] Public or Confidential

[3] Delivery data of latest edition

[4] Public or Confidential

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

1.5.3 Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu

Reference	Title	Delivery Date[5]	Dissemination Level[6]
Description			
D4.1	Solution PJ11-A2: V1 Data Pack	30/04/2018	PU
The datapack contains VALR, OSED-SPR-INTEROP, TS-IRS and CBA for the ACAS Xu solution at V1 maturity level.			
D4.2	Solution PJ11-A2: V2 Data Pack	16/09/2019	PU
The datapack contains VALR, OSED-SPR-INTEROP, TS-IRS and CBA for the ACAS Xu solution at V2 maturity level.			

Table 3: Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu Deliverables

1.5.4 Solution ACAS for Commercial Air Transport specific operations – ACAS Xo

Reference	Title	Delivery Date[7]	Dissemination Level[8]
Description			
D5.1	Solution Enhanced Air and Ground Safety Nets Final Project Report Data Pack	30/08/2019	PU
The datapack contains V2 VALR, OSED-SPR-INTEROP, TS-IRS and CBA for the ACAS Xo solution.			

Table 4: Solution ACAS for Commercial Air Transport specific operations – ACAS Xo Deliverables

[5] Delivery data of latest edition

[6] Public or Confidential

[7] Delivery data of latest edition

[8] Public or Confidential

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

1.5.5 Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+

Reference	Title	Delivery Date[9]	Dissemination Level[10]
Description			
D6.1	Solution PJ11 A4: V1 SA+ Data Pack	30/04/2018	PU
The Data Pack contains SPR-INTEROP/OSED, VALR, TS-IRS, and CBA for the SA+ solution at V1 maturity level.			
D6.2	Solution PJ11 A4: V2 SA+ Data Pack	06/09/2019	PU
The Data Pack contains SPR-INTEROP/OSED, VALR, TS-IRS, and CBA for the SA+ solution at V2 maturity level			

Table 5: Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+ Deliverables

[9] Delivery data of latest edition

[10] Public or Confidential

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

2 Links to SESAR Programme

2.1 Contribution to the ATM Master Plan

Code	Name	Project contribution	Maturity at project start	Maturity at project end
PJ.11-G1	Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPs information.	The solution aims at contributing to an improved Short Term Conflict Alert and None Transgression Zone ground based safety nets in different operational environments by increasing the effectiveness on alert declaration, positive impact on safety, positive impact on human performance and increasing the trust of the controllers in the system	V1	V2
PJ.11-A1	ACAS Xa European Acceptability Framework	The project provided useful data to US development team to improve the system performance and participated in its standardisation (MOPS in December 2018). The corresponding OI step (CM-0808-a) and enabler (A/C-54a) were refined and updated through a CR. EATMA modelling has also been updated at the end of the project. Technical feasibility was confirmed (a prototype exists) and operational benefits exist although it was not possible to conclude if all indicators were green for European acceptability.	V2	V3
PJ.11-A2	Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu	The solution aims to support the ATM integration and safe use of commercial RPAS through the development of RPAS-dedicated variant of ACAS X – ACAS Xu. Operational Collision Avoidance System for RPAS is necessary (but not sufficient by itself) condition for RPAS to operate in non-segregated airspace.	V0	V2

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

PJ.11-A3	ACAS for Commercial Air Transport specific operations – ACAS Xo	This solution addresses a specific function of the ACAS X system allowing the use of dedicated alerting logic for a selected intruder. Such a function aims to solve specific operational problems (such as approaches to closely spaced parallel runways) where a nominal ACAS logic generates high numbers of disruptive/nuisance alerts.	V1	V1 ongoing
PJ.11-A4	Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems (previously (CR 03337): Airborne Collision Avoidance for General Aviation and Rotorcraft - ACAS Xp)	The project presents a solution for lowering the risk of mid-air collision between a TCAS II equipped and un-equipped aircraft. The solution consists in enhancement of an already standardized TSAA (Traffic Situation Awareness with Alerts) application, denoted as TSAA+ or SA+. The RA issued by the TCAS II can be made available to the crew of an unequipped aircraft to prevent an undesirable manoeuvre w.r.t. the RA. TSAA+ can be used in any type of airspace, visibility and rules and is aimed at aircraft not under TCAS II mandate.	V0	V2

Table 6: Project Maturity

2.2 Contribution to Standardisation and regulatory activities

Project members are active participants in the Standardisation of ACAS Xa/Xo and ACAS Xu. The Validation work of The project was input in support to the iterative development ("tuning runs") of the systems.

Beyond the tuning runs, the EXE05 of the solution "ACAS Xa European Acceptability Framework" was part of the European Verification/Validation of ACAS Xa that will provide the evidence required for EASA to start the Rule Change and ETSO processes required in order for ACAS Xa operations to be permitted in Europe.

The relevant Standards developed in this context are:

EUROCAE ED-256/RTCA DO-385 ACAS Xa/Xo MOPS (published)

EUROCAE ED-256/RTCA DO-385 ACAS Xa/Xo MOPS Change 1 (published)

EUROCAE ACAS Xu MOPS (due to be published end 2020))

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

3 Conclusion and Next Steps

3.1 Conclusions

3.1.1 Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information

This solution reached V2 maturity level which is documented in the D2.1 Data Pack.

Significant safety improvement results were achieved, based on quantitative results. The time needed in the prediction of future alerts (STCA and NTZ) is reduced. Reduction of nuisance alerts (STCA and NTZ) number is confirmed.

The level of trust the alerts presentation increased, the reduction of workload in terms of reduction of nuisance alerts number was confirmed. The enhanced STCA and NTZ ground based safety nets by means of the use of DAPs received via ADS-B and Mode-S information is able to advance the prediction of future alerts, the effectiveness and increment of human performance is confirmed in the alerts declaration.

Average reduction about 60-65% in the nuisance alerts and the anticipation in the declaration alert until 15-20s before in the best cases confirm the compliance with the safety validation target -0,74% TMA HC and -0,70% ER HC, aligned with reduction due to SESAR2020 PJ11-G1 solution improvements in the total number of fatal accidents per year - Directly related with the reduction on the number of situations derived on Imminent Collision/Imminent Transgression (precursor from the SAR)

3.1.2 Solution ACAS Xa European Acceptability Framework

This solution has achieved V3 maturity level which is documented in the D3.1 Data Pack..

As an improvement over current TCAS, the concept is solid and is well supported by enhancements in surveillance and alert determination. Overall technical feasibility was proven by the release of a pre-industrial prototype embedding Run 15.3. There is no issue in operational feasibility: in continuity with TCAS, no operational change is needed for TMA and ER environments. The new approach is still compatible with the SESAR1 TCAP feature.

However, the operational performance results collected in the V3 validation exercises (see V3 validation report D3.1.060) may lead to a Change Proposal in ACAS-Xa. Further operational analysis (by EUROCAE / EASA in collaboration with RTCA /FAA) will examine if operational issues are show stoppers for ACAS Xa deployment or if any identified issues may be captured as changes for a Revision B of ACAS Xa.

3.1.3 Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu

The solution has achieved V2 maturity level which is documented in the D4.2 Data Pack.

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

According the obtained results Runs 4.x of ACAS Xu seem to perform well its intended function and has positive impact on safety – the only KPA addressed by the solution.

Several open points were identified in terms of non-favourable RAs whether issued by ACAS Xu or triggered on-board conflicting manned aircraft. Further simulations with a more realistic environment (encounter model, operational definition) and using Run 5+ version of ACAS Xu are needed to confirm and refine these results in V3 phase. In addition, as stated above, the human performance and additional operational acceptability criteria should be addressed in V3 phase.

3.1.4 Solution ACAS for Commercial Air Transport specific operations – ACAS Xo

The current solution maturity level is V1 ongoing with artefacts summarized in the D5.1 Data Pack.

From the validations performed in this PJ.11-A3 project, we can conclude, that ACAS Xo as defined in the ACAS Xa+Xo MOPS (RTCA DO-385/ EUROCAE ED-256 published in October 2018) is technically feasible since no technical blocking point was observed (pilots were able to perform approaches with ACAS Xo activation). However, from operational point of view, the validation results do not support V2 maturity for EU airspace. While ACAS Xo system requirements are specified in ACAS Xa+Xo MOPS, there is no detailed operational definition published for ACAS Xo procedures, with only a high level Concept of operation currently available. Also, there is currently no use-cases identified in Europe for the two ACAS Xo modes (CSPO and DNA) as defined in the ACAS Xa+Xo MOPS. Therefore from an operational point, the ACAS Xo benefit in Europe is not obvious.

3.1.5 Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+

The solution has achieved V2 maturity level which is documented in the D6.2 Data Pack.

TSAA+ has shown clear benefits in terms of safety (KPA SAF): the Validation Targets assigned to the solution were achieved.

General aviation, rotorcraft and state aircraft not under TCAS II mandate can easily decrease of mid-air collision with a TCAS II equipped aircraft through the use of information about the intruder's resolution advisory. TSAA+ is based on ADS-B In functionality. If the user is also equipped with at least mode C transponder, the safety benefits increase even further.

3.2 Plan for next R&D phase (Next steps)

3.2.1 Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information

Regarding STCA objective of the solution, following aspects should be taken into account in order to improve the configuration of the system parameters directly involved in the Short Term Conflict Alert ground safety net effectiveness, human performance and safety aspects:

- Refinements in the new trajectory extrapolation algorithms.
- Time to conflict (separation mode is compromised) which would be considered for triggering the alert prediction/declaration and violation.
- Distance used as triggering of alert prediction/declaration and violation (related to the trajectory extrapolation algorithms).
- Include more variability in scenarios to avoid learning effect and more variability during run.
- Possibility of relationships with other groups of projects interested on incorporate and test the Enhanced STCA ground safety net module in an En-Route and TMA Operational Environments (separation tools projects).
- Presentation in the CWP of additional information related with the new information received from the aircraft (DAPs more relevant and useful).
- To put more emphasis in the study of face-face vertical manoeuvres with FSSA / ROCD parameters and ROCD high value.

Regarding the NTZ objective for this solution, the following aspects should be taken into account in order to improve the configuration of the system parameters directly involved in the Non Transgression Zone ground safety net effectiveness, human performance and safety aspects:

- The most efficient Non Transgression Zone area definition (length, width and location related to the independent parallel runways). These definitions would be dependent of the airport in particular, arrivals procedures previously defined…
- Refinements in the new already defined trajectory extrapolation algorithms.
- Time to transgression which would be considered for triggering the transgression alert prediction/declaration and violation.
- Distance used as triggering of transgression alert prediction/declaration and violation (related with the trajectory extrapolation algorithms).
- In order to allow a progressive adaptation and familiarization of the controllers as a first step with this new safety net module system (functionality), it is recommended to provide this new module to support day-to-day controller tasks. Thus the controller can observe and use

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as support this new safety net in his day to-day work, also providing inputs/suggestion to continue improving this new module whilst in shadow mode operations.

- Include more variability in scenarios to avoid learning effect and more variability during run.
- Presentation in the CWP of additional information related with the new information received from the aircraft (DAPs more relevant and useful).

3.2.2 Solution ACAS Xa European Acceptability Framework

As pointed out above, the next step is for EUROCAE and EASA to examine the results.

If EASA accepts ACAS Xa in Europe, then no further R&D would be needed for ACAS Xa proper, although simulations with ACAS Xa will be necessary when validating ACAS Xu, in order to check their interoperability in Europe.

After acceptability is recorded, the regulatory framework will be developed and deployment will follow. As no mandate is planned and cost of equipment is not trivial (see CBA), it is expected that deployment will be driven by current TCAS II attrition and may last between two and three decades. Deployment monitoring should be established in Europe to catch any unforeseen problem as soon as it occurs. Flight crew and controller training should include information on the new system, especially during the transition period about operational situations where TCAS and ACAS Xa alert differently.

If ACAS Xa in its current state is not considered as acceptable in Europe, then further development by the US teams / RTCA / EUROCAE is expected to take place and Europe will have to run other simulations to check that areas of concern were addressed and that no regression took place.

3.2.3 Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu

The following recommendations were identified by PJ.11-A2 for next validation and R&D activities:

- Assess the results with the newest ACAS Xu Run available (5+).
- Include human performance and deeper operational acceptance studies.
- Integrate multiple threats in the assessment.
- Focus on different airspace classes, aircraft environment, and aircraft performances – representing them through advanced encounters model (considering ongoing work in CAFÉ program).
- Identified open points concerning operational behaviour needs to be addressed in refinements of European acceptability criteria.

Concerning the latter, the initial version of European acceptability criteria was developed and delivered as V2 OSED annex. These criteria will need to be refined especially as the operational definition of RPAS integration into European ATM will mature.

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The V3 phase of ACAS Xu activities is planned in the initial V3 VALP describing 10 exercises as a supporting document for V2 maturity gate. During the gate, it was identified that it is essential:

- to ensure that existing operational requirements are properly referenced for the future project (i) from OSED V2 §4 (ii) from the existing standards (iii) from EDA, and
- to assess involvement of the RPAS pilot in an operational validations.

3.2.4 Solution ACAS for Commercial Air Transport specific operations – ACAS Xo

As the next steps in ACAS Xo development, the following topics should be addressed:

- A new operational concept needs to be defined with focus on agreement between pilots and ATC on the procedure how the pilots identify and designate the right aircraft for correct ACAS Xo mode. It should respect the principle of independence between airborne safety nets and ground operations.
- Definition of appropriate cockpit procedures for pilots about the use of ACAS Xo.
- The need to maintain safety net to be carefully investigated for each proposed procedure.
- Investigations to identify, where
  - ✓ numerous nuisance RAs are generated or pilots ignore RAs in Europe
  - ✓ further use cases for DNA mode are in Europe
  - ✓ CSPO-3000 mode is useful – which minimal and maximal distance between parallel runways is applicable for modified RA thresholds

3.2.5 Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+

The work performed so far covered the main conceptual and technological elements. In a next phase only refinement and/or extension of some activities or elements is necessary. It is recommended to:

- Refine the concept of operation in terms of airspace user categorization, information presented to pilot and potential transition issues.
- Focus on HMI development including considering Class 1 TSAA+ development and validation.
- Include more complex scenarios (i.e. three-aircraft scenarios) and, if available, more samples of real European encounters for all airspace user categories.
- Develop training on TSAA+ for pilots.
- Validate all of the above through a set of real flight tests.

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

4 References

4.1 Project Deliverables

4.1.1 Solution Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPS information

[1] Solution PJ11-G1: V2 Initial OSED, D2.1.011,29/09/2017

[2] Solution PJ11-G1: V2 Initial VALP, D2.1.021, 29/09/2017

[3] Solution PJ11-G1: V2 Initial TS/IRS, D2.1.031, 13/03/2018

[4] Solution PJ11-G1: EXE-01 AN, D2.1.040, 06/02/2019

[5] Solution PJ11-G1: EXE-02 AN, D2.1.050, 06/02/2019

[6] Solution PJ11-G1: EXE-03 AN, D2.1.051, 06/02/2019

[7] Solution PJ11-G1: V2 VALR, D2.1.060, 08/07/2019

[8] Solution PJ11-G1: V2 Final OSED, D2.1.010, 19/07/2019

[9] Solution PJ11-G1: V2 Final VALP, D2.1.020, 08/02/2019

[10] Solution PJ11-G1: V2 TS/IRS, D2.1.030, 08/07/2019

[11] Solution PJ11-G1: V2 CBA, D2.1.070, 31/07/2019

[12] Solution PJ11-G1: V3 Initial VALP, D2.1.080, 13/09/2019

4.1.2 Solution ACAS Xa European Acceptability Framework

[13] PJ.11-A1, "SESAR Solution PJ.11-A1: Validation Plan (VALP) for V3", D3.1.010, Edition 00.01.00, 5 June 201

[14] PJ.11-A1, "SESAR 2020 TS IRS for ACAS Xa", D3.1.040, Edition 00.01.01, 3 October 2019

[15] PJ.11-A1, "SESAR Solution PJ.11-A1: Cost Benefit Analysis report for V3", D3.1.050, Edition 00.01.00, 3 October 2019

[16] PJ.11-A1, "SESAR Solution PJ.11-A1: Validation Report (VALR) for V3", D3.1.060, Edition 00.01.01, 25th October 2019

4.1.3 Solution Airborne Collision Avoidance for Remotely Piloted Aircraft Systems – ACAS Xu

[17] Solution PJ11-A4: EXE-08 AN, D6.3.030, 00.01.00, 16/01/2019

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

[18] Solution PJ11-A2: EXE-01 AN, D4.1.040, 00.00.01, 01/08/2017

[19] Solution PJ11-A2 V1: V1 VALP, D4.1.030, 00.00.02, 16/10/2017

[20] Solution PJ11-A2: V1VALR, D4.1.050, 31/01/2018

[21] Solution PJ11-A2: V1 OSED, D4.1.060, 19/03/2018

[22] V1 Initial CBA, D4.1.080, 00.00.02, 04/04/2018

[23] Solution PJ11-A2 V2: V2 VALP, D4.2.010, 00.01.01, 02/10/2018

[24] Solution PJ11-A2: EXE-02 AN, D4.2.020, 00.01.00, 05/06/2018

[25] Solution PJ11-A2: EXE3 AN, D4.2.021, 04/09/2018

[26] Solution PJ11-A2: EXE4 AN, D4.2.022, 04/09/2018

[27] Solution PJ11-A2 V2: V2 VALR, D4.2.030, 00.01.01, 23/07/2019

[28] Solution PJ11-A2: V2 CBA (Cost Assessment), D4.2.060, 00.01.00, 23/07/2019

[29] Solution PJ11-A2 V2: OSED-SPR-INTEROP, D4.2.040, 00.01.01, 08/08/2019

[30] Solution PJ11-A2: V2 TS, D4.2.050, 00.01.01, 16/09/201

[31] V3 VALP Initial, D4.2.070, 00.00.03, 16/09/2019

4.1.4 Solution ACAS for Commercial Air Transport specific operations – ACAS Xo

[32] Solution PJ11-A3: V2 VALP, D5.1.010, 00.01.00, 30/03/2018

[33] Solution PJ11-A3: EXE-02 AN, D5.1.030, 00.01.00, 18/01/2019

[34] Solution PJ11-A3: V2 VALR, D5.1.040, 01.00.01, 09/08/2019

[35] Solution PJ11-A3: V2 OSED-SPR-INTEROP, D5.1.050, 01.00.02, 30/08/2019

[36] Solution PJ11-A3: V2 TS-IRS, D5.1.060, 01.00.01, 09/08/2019

[37] Solution PJ11-A3: V2 CBA, D5.1.070, 01.00.02, 28/08/2019

[38] D5.1 - Solution PJ11-A3: V2 Data Pack, D5.1, N/A, 04/09/2019

[39] Solution PJ11-A3: V3 initial VALP, D5.1.080, 01.00.01, 15/10/2019

4.1.5 Solution Enhanced traffic situation awareness of GA/R/StA addressing interoperability with collision avoidance systems - TSAA+

[40] Solution PJ11-A4: V1 SA+ Initial OSED, D6.1.011, 00.01.00, 30/06/2017

(*): The former name of A1 is: “Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)”. Change of A1 title occurred during the V3 gate. A change Request is in process.

[41] Solution PJ11-A4: V1 VALP, D6.1.010, 00.01.00, 31/07/2017

[42] Solution PJ11-A4: EXE-01 AN, D6.1.030, 00.01.00, 31/08/2017

[43] Solution PJ11-A4: EXE-02 AN, D6.1.040, 00.01.00, 31/08/2017

[44] Solution PJ11-A4: EXE-03 AN, D6.1.050, 00.01.00, 31/08/2017

[45] Solution PJ11-A4: V1 SA+ VALR, D6.1.060, 00.01.00, 28/02/2018

[46] Solution PJ11-A4: V1 SA+ OSED-INTEROP, D6.1.070, 00.01.01, 03/05/2018

[47] Solution PJ11-A4: V1 SA+ Initial CBA, D6.1.081, 00.00.02, 03/04/2018

[48] D6.1 Solution PJ11-A4: V1 Data Pack, D6.1, N/A, 28/05/2018

[49] Solution PJ11-A4: V2 SA+ Initial VALP, D6.1.080, 00.01.00, 23/04/2018

[50] Solution PJ11-A4: V2 VALP, D6.2.010, 00.01.00, 19/11/2018

[51] Solution PJ11-A4: EXE-04 AN, D6.2.020, 00.01.00, 16/01/2019

[52] Solution PJ11-A4: EXE-05 AN, D6.2.030, 00.01.00, 16/01/2019

[53] Solution PJ11-A4: EXE-06 AN, D6.2.831, 00.01.00, 17/01/2019

[54] Solution PJ11-A4: EXE-07 AN, D6.3.020, 00.01.00, 16/01/2019

[55] Solution PJ11-A4: EXE-08 AN, D6.3.030, 00.01.00, 16/01/2019

[56] Solution PJ11-A4: V2 SA+ VALR, D6.2.040, 00.01.04, 20/08/2019

[57] Solution PJ11-A4: V2 SA+ OSED-SPR-INTEROP, D6.2.050, 00.01.00, 20/08/2019

[58] Solution PJ11-A4: V2 SA+ TS-IRS, D6.2.060, 00.01.00, 27/08/2019

[59] Solution PJ11-A4: V2 SA+ CBA, D6.2.070, 00.01.00, 19/07/2019

[60] D6.2 - Solution PJ11-A4: V2 Data Pack, D6.2, N/A, 06/08/2019

[61] Solution PJ11-A4: V3 initial VALP, D6.3.060, 00.01.00, 30/08/2019

4.2 Project Communication and Dissemination papers

[62] WG-75 49th Meeting, EUROCONTROL, 31 January 2017

[63] WG-75 50th Meeting, Phoenix, 9 March 2017

[64] WG-75 52nd Meeting, RTCA, 21 September 2017

[65] WG-75 53rd Meeting, SJU, 5 October 2017

[66] WG-75 55th Meeting, EUROCONTROL, 9 January 2018

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

[67] WG-75 56th Meeting, RTCA, 8 March 2018

[68] WG-75 57th Meeting, RTCA, 17 May 2018

[69] Presentation to EASA staff 15 November 2018

[70] PJ11-A3 ACAS Xo Workshop 26/27 November 2018

[71] PJ11-G1 Open Day 6 Mar 2019

[72] WG-75 62nd Meeting, RTCA, 13 June 2019

[73] WG-75 63rd Meeting, RTCA, 19 September 2019

Appendix A Glossary of Terms, Acronyms and Terminology

A.1 Glossary of terms

Term	Definition	Source of the definition
Corrective advisory	Corrective advisory – A resolution advisory that instructs the pilot to deviate from current vertical rate, for example a Level Off RA when the aircraft is climbing.	*EUROCONTROL ACAS Guide (December 2017)*
Intruder	A transponder-equipped aircraft within the surveillance range of ACAS for which ACAS has an established track.	*EUROCONTROL ACAS Guide (December 2017)*
Near Midair Collision (NMAC)	Two aircraft simultaneously coming within 100 feet vertically and 500 feet (0.08 NM) horizontally.	*EUROCONTROL ACAS Guide (December 2017)*
Nuisance alert (RA)	In terms of compatibility with Air Traffic Management, an RA shall be considered a "nuisance" unless, at some point in the encounter in the absence of TCAS II, the horizontal separation and the vertical separation are simultaneously less than 750 feet vertically and 2 NM horizontally (if above FL100) or 1.2 NM (if below FL100).	*EUROCONTROL ACAS Guide (December 2017*

Table 7: Glossary

A.2 Acronyms and Terminology

Term	Definition
ACAS	Airborne Collision Avoidance System
ACAS Xa	Airborne Collision Avoidance System X – active surveillance (a member of the ACAS X family that is designed to replace TCAS as seamlessly as possible)
ADS-B	Automatic Dependent Surveillance - Broadcast
ATM	Air Traffic Management
CAFÉ	Collision Avoidance Fast-time Evaluator

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CBA	Cost Benefit Analysis
CSPO-3000	Closely Spaced Parallel Operations (3000 feet)
CWP	Controller Working Position
DAA	Detect And Avoid
DAPS	Downlinked Aircraft Parameters
DNA	Designated No Alerts (mode)
EASA	European Aviation Safety Agency
EATMA	European ATM Architecture
EDA	European Defence Agency
ETSO	European Technical Service Order
EUROCAE	EURopean Organisation for Civil Aviation Equipment
FAA	Federal Aviation Administration (USA)
FSSA	Final State Selected Altitude
MIT	Massachusetts Institute of Technology
NMAC	Near Mid-air Collision
NTZ	Non Transgression Zone
PMP	Project Management Plan
RA	Resolution Advisory
ROCD	Rate of Climb/Descent
RPAS	Remotely Piloted Aircraft
RTCA	RTCA Inc. (formerly Radio Technical Commission on Aeronautics)
RTS	Real Time Simulation
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
STCA	Short Term Conflict Alert
STM	Surveillance and Tracking Module
TA	Traffic Advisory

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

TCAP	TCAS Alert Prevention
TCAS	Traffic alert and Collision Avoidance System
TRM	Threat Resolution Module
TSAA	Traffic Situation Awareness with Alerts

Table 8: Acronyms and technology

(*): The former name of A1 is: “Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)”. Change of A1 title occurred during the V3 gate. A change Request is in process.

(*): The former name of A1 is: “Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)”. Change of A1 title occurred during the V3 gate. A change Request is in process.

Appendix B Solution ACAS Xa European Acceptability Framework : Report of the second run of EXE-05

As recommended in the V3 VALR [16], EXE-05 was performed a second time in order to waive the limitations and lack of conclusions experiences in the first place. As agreed beforehand with the SJU and mentioned in the V3 VALR, the second run of EXE-05 is reported in this appendix to the FPR. Necessary changes to the V3 VALR consolidated parts resulting from the second run are included in section B.3.

B.1 Validation setup

The following information is a reminder. More details can be obtained in the V3 VALP [13] and in the V3 VALR [16].

B.1.1 Validation objectives

There were three validation objectives for this validation:

- Safety is improved when operating ACAS Xa TRM in the European environment
- Operational compatibility of ACAS operations with ATC practices is improved when operating ACAS Xa TRM in the European environment
- ACAS alerts are more acceptable by pilots when operating ACAS Xa in the European environment

B.1.2 Validation scenarios

The objectives are formulated in reference to the current ACAS (TCAS II v7.1) performance, so the reference scenarios are those where only TCAS II v7.1 is active, whereas the solution scenarios include either only ACAS Xa Run 15.4 or a mix of ACAS Xa Run 15.4 and TCAS II v7.1.

The following table summarises the validation scenarios.

Encounter types	Logic (s)	
	Reference scenarios	Solution scenarios
European pair-wise safety-related encounters	TCAS II v7.1	ACAS Xa ACAS Xa + TCAS
European pair-wise Überlingen-like encounters	TCAS II v7.1	ACAS Xa ACAS Xa + TCAS
European day-to-day ATM encounters	TCAS II v7.1	ACAS Xa ACAS Xa + TCAS
Local radar data encounters	TCAS II v7.1	ACAS Xa ACAS Xa + TCAS

(*): The former name of A1 is: “Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)”. Change of A1 title occurred during the V3 gate. A change Request is in process.

The two first encounter types were used to assess the safety objective and cover European encounters that are likely to result in an ACAS RA (less than 500 ft horizontal distance at closest approach). Überlingen-like encounters reproduce geometries close to the one existing in the Überlingen accident.

The two last encounter types were used to assess the operational suitability objectives and cover European encounters that are likely to result at least in an ACAS TA. Local radar encounters are useful to highlight performance difference between the overall view and specific locations.

The other key elements for the scenarios are that:

- the flight crew reacts to an RA according to the ACAS expected response (aka standard pilot response)
- ACAS Xa scenarios were run with surveillance data tagged as coming from active surveillance then with surveillance data tagged as coming from passive surveillance

B.1.3 Validation framework

The first three sets of encounters described above were generated from encounter models reproducing the characteristics of European real encounters but allowing to generate as many encounters as needed for statistical significance without having to record years of radar data. The existing safety models are AVAL and SA01 while the CRÈME-S model has been developed within the project. PASS is the operational model.

The following table gives the size of each encounter set that was used for the validation.

Encounter set	Size
AVAL model	5 000 000
CRÈME-S model	1 000 000
SA01 (Überlingen) model	100 000
PASS model	100 000
Local radar data	2 000

The validation framework also includes a simulation software that contains the various ACAS logic to be tested, several pilot response models (including the standard response model) and two altimetry error models (an RVSM model for aircraft able to fly above FL290 and an ICAO model for the others).

After simulation of an ACAS logic on a set of encounters, specific tools from the validation framework allows to count occurrences of pre-determined conditions, allowing to produce performance indicators. The indicators for this validation were developed within SESAR as well as the desired threshold for success. They are divided into safety and operational compatibility indicators. Furthermore, they are classified in two categories according to their perceived criticality in terms of acceptability in the European airspace:

- P1 indicators should all reach the desired threshold;
- P2 indicators may not all reach the desired threshold if the overall result is judged worth the highlighted limitations.

(*): The former name of A1 is: "Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)". Change of A1 title occurred during the V3 gate. A change Request is in process.

B.2 Validation Results

B.2.1 Summary of validation Results

(*): The former name of A1 is: “Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations (ACAS Xa)”. Change of A1 title occurred during the V3 gate. A change Request is in process.

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
EX5-OBJ-11.A1-V3-VALP-001	Validate that safety is improved when operating ACAS Xa in European environment	EX5-CRT-11.A1-V3-VALP-001-001	The rate of near mid-air collisions is significantly decreased with ACAS Xa compared to TCAS II in two-aircraft encounters in all altitude layers	All	Overall positive results for risk ratios (assuming perfect pilot reaction to RAs): • Reduction for most of the computed risk ratios However, the following risks have been identified: • Limited increase in overall risk ratio above FL135 due to EU encounters: Poor performance in head-on encounters with a level equipped aircraft and an unequipped intruder crossing the equipped aircraft altitude at a high vertical rate (>4,000fpm) • ACAS Xa behaviour difficult to understand on some particular encounters due to probabilistic approach (vs. TCAS II deterministic approach) • More Increase RAs with ACAS Xa, that if not followed increases the risk ratio by about 30%[11]	**NOK (due to EU encounters at high altitudes)**

[11] This increase could be acceptable with a recommendation of using AP/FD TCAS with ACAS Xa to ensure Increase RAs are adequately followed and thus safety benefits ensured

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
		EX5-CRT-11.A1-V3-VALP-001-002	SA01 issue is solved with ACAS Xa (at least as done by TCAS II v7.1 or better)	All	Overall positive results for risk ratios: • Reduction for all of the computed risk ratios However, the following risks have been identified: • New type of Reverse RA introduced by ACAS Xa: ○ Reverse Crossing RAs when aircraft are up to ~500ft apart are generated by ACAS Xa (vs. 150ft with TCAS II) to obtain major benefits on non-response scenarios (e.g. Überlingen-like encounters) ○ Up to 3 Reverse RAs in the sequence (vs. 2 with TCAS II)	**OK (with a recommendation of using AP/FD TCAS with ACAS Xa to ensure stressful RAs are adequately followed and safety benefits ensured)**
		EX5-CRT-11.A1-V3-VALP-001-003	ACAS Xa is at least as robust as TCAS II against reasonable variability in response to RAs	All	ACAS Xa shows to be robust to non-responsive pilots (e.g. up to 50% reduction in Risk Ratio in scenarios where one of the pilots does not follow the RAs compared to TCAS II) The robustness to typical pilot responses (compared to standard pilot responses) has, nevertheless, not been assessed	**Inconclusive (due to typical pilot responses not assessed)**

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
		EX5-CRT-11.A1-V3-VALP-001-004	All safety benefits are still there when operating in mixed ACAS Xa / TCAS II environment	All	Overall positive results for risk ratios during ACAS Xa deployment phase However, the following risks have been identified: • More Stressful RAs (e.g. Increase RAs) and in particular in mixed TCAS II and ACAS Xa environment more Reverse RAs, asymmetric Crossing RAs and multiple Reverse RAs (up to 3, especially on Überlingen-like encounters)	**OK (with a recommendation of using AP/FD TCAS with ACAS Xa to ensure stressful RAs are adequately followed and safety benefits ensured)**
		EX5-CRT-11.A1-V3-VALP-001-005	The risk of near mid-air collision is significantly decreased with ACAS Xa compared to TCAS II in three-aircraft encounters	All	Not assessed	**Inconclusive (since not assessed)**

Founding Members

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status

EX5-OBJ-11.A1-V3-VALP-002	Validate that the operational compatibility of ACAS operations with ATC practices is improved when operating ACAS Xa in European environment	EX5-CRT-11.A1-V3-VALP-002-001	Operationally undesired alerts (from ATC perspective) are significantly decreased with ACAS Xa compared to TCAS II	All	Great overall reduction of RA encounters with ACAS Xa, yet not the same overlap between TCAS II and ACAS Xa encounters triggering RAs.
					
					Some decrease in RA triggering in some geometries:
					• 1,000ft single Level-Off encounters:
					  ○ ACAS Xa significantly removes RAs during encounters with vertical speed > 1,500fpm
					• 1,000ft double Level-Off encounters:
					  ○ ACAS Xa significantly removes Climb and Descend RAs for this geometry
					• 500ft level-level encounters:
					  ○ Almost all preventive RAs removed by ACAS Xa
					
					However, some increase in RA triggering in some other geometries:
					• 1,000ft single Level-Off encounters:
					  ○ ACAS Xa significantly adds RAs during encounters with vertical speed < 1,500fpm
					• 1,000ft Jump encounters:
					  ○ Increase of undesired RAs triggered by ACAS Xa (e.g. additional Maintain RAs triggered by ACAS Xa after aircraft vertical crossing) resulting in altitude overshoot and large deviations
						NOK (due to 1,000ft single Level-Off encounters with vertical speeds below 1,500fpm and 1,000ft Jump encounters)

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
		EX5-CRT-11.A1-V3-VALP-002-002	Alerts are less disruptive to ATC with ACAS Xa compared to TCAS II	All	Some good results: • Less RA encounters with large horizontal separation Some not good results: • Higher vertical deviations resulting from ACAS Xa RAs due to later weakening RAs with ACAS Xa[12] • More RA encounters with large vertical separation (above 2,000ft at CPA) • Increase of undesired RAs triggered by ACAS Xa during 1,000ft Jump geometries (e.g. additional Maintain RAs triggered by ACAS Xa after aircraft vertical crossing) resulting in altitude overshoot and large deviations	**NOK (due to increase in vertical deviations)**
		EX5-CRT-11.A1-V3-VALP-002-004	All operational benefits are still there when operating in mixed ACAS Xa / TCAS II environment	All	Great overall reduction of RA encounters through ACAS Xa deployment, yet not the same overlap between TCAS II and ACAS Xa encounters triggering RAs which results in some increase in RA triggering in some specific mixed ACAS Xa and TCAS II encounters (cf. to EX5-CRT-11.A1-V3-VALP-002-001)	**OK**

[12] ICAO requirements not achieved on PASS-adapted encounter model for ACAS Xa

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
EX5-OBJ-11.A1-V3-VALP-003	Validate that ACAS alerts are more acceptable by pilots when operating ACAS Xa in the European environment	EX5-CRT-11.A1-V3-VALP-003-001	Nuisance alerts are significantly decreased with ACAS Xa compared to TCAS II	All	Same trends observed in pilot perspective (aircraft) and ATC perspective (encounter). Cf. EX5-CRT-11.A1-V3-VALP-002-001	**NOK (due to 1,000ft single Level-Off encounters with vertical speeds below 1,500fpm and 1,000ft Jump encounters)**

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
		EX5-CRT-11.A1-V3-VALP-003-002	ACAS Xa alerts lead to less stressful situations for pilots when compared to TCAS II	All	More Stressful situations for pilots: • Enlarged number of very close encounters without Corrective RAs (and even without any RA), but remaining in the relatively same triggering envelope than TCAS II • More Increase RAs • More Crossing RAs and very complex RA sequences on equipped-equipped encounters • More Reverse RAs (including Reverse Crossing RAs when aircraft are up to ~500ft apart), asymmetric Crossing RAs and multiple Reverse RAs (up to 3, especially on Überlingen-like encounters) in mixed TCAS II and ACAS Xa environment • On Überlingen-like encounters, 60% of ACAS Xa Reverse RAs are Crossing RAs and 25% of ACAS Xa Reverse Crossing RAs are triggered when aircraft are more than 300ft apart (vs. 0% with TCAS II, since unauthorized above 150ft with TCAS II)	NOK
		EX5-CRT-11.A1-V3-VALP-003-003	ACAS Xa alerts are at least as compatible with see and avoid operations (i.e. alerts are issued before pilots generally believe avoiding action is needed) as TCAS II	All	More Stressful situations for pilots: • Enlarged number of very close encounters without Corrective RAs (and even without any RA), but remaining in the relatively same triggering envelope than TCAS II • More cases of RAs close to TAs (or with no TAs) with ACAS Xa	NOK

Validation Objective ID	Validation Objective Title	Success Criterion ID	Success Criterion	Sub-OEs	Validation Results	Validation Objective Status
		EX5-CRT-11.A1-V3-VALP-003-004	ACAS Xa TAs are triggered to permit pilots to well prepare to RAs	All	More cases of RAs close to TAs (or with no TAs) with ACAS Xa	**NOK**

B.2.2 Detailed results

The success or failure of the previous criteria was determined using the results of the indicators as defined in SESAR 4.8.1 D101.

In the following tables, the "Scope" column indicates whether the metric is computed on the whole set ("Overall") of encounters, on subsets of encounters per altitude layers ("ALT") or on a solution scenario involving a mix of TCAS II v7.1 and ACAS Xa Run 15.4 ("INTEROP").

The colour code of the cells is the following:

Threshold satisfied & significance achieved
Threshold satisfied & significance not achieved
Diverging results for different encounter sets
Threshold not satisfied & significance not achieved
Threshold not satisfied & significance achieved

EE stands for Equipped-Equipped, a subset of encounters where both aircraft are equipped with an ACAS. LO stands for Level-Off, a situation where one (single LO) or both (double LO) of the aircraft level off, usually 1,000 ft apart (1,000 ft LO). A specific RA, the LOLO RA, requests the pilot to perform a level-off.

1. Priority 1 metrics

The following table provides the results for priority 1 safety and operational performance metric.

Metric	Rationale	Qualitative Threshold	Guidance Value	Scope	Results
P1 Safety metrics					
Pilots follow the RAs					
Overall airspace					
Risk Ratio	To be safer (from a statistical point of view)	At least a minor improvement	Minor = at least -5%	Overall	-16% (-2.2)
				ALT	Reduction (~ -18%) below FL135 Minor increase (+1%) above FL135
Induced Risk Ratio	Inducing more collisions is not acceptable	At least no increase	/	Overall	-36% (-1.8)
Unresolved Risk Ratio	To be at least as efficient as TCAS II in resolving NMACs	At least no increase	/	Overall	-5% (-0.4)
Very close encounters	To avoid very close encounters without Corrective RAs where pilots would want to have a Corrective RA	Corrective RAs triggered in nearly all very close encounters	Nearly all = at least 95% *(same order of magnitude as TCAS II)*	Overall	81% in TMA and 86% in En-Route (vs. 92% and 93% for TCAS)
EE subset					
Risk Ratio in EE encounters	To be safer (from a statistical point of view)	At least a minor improvement	Minor = at least -5%	Overall	-16% (-2.0) with extended slow horizontal convergence encounters

Metric	Rationale	Qualitative Threshold	Guidance Value	Scope	Results
				ALT	Reduction with extended slow horizontal convergence encounters (from -12% to -94% depending on the altitude bands)
				INTEROP	Increase observed on the initial set (i.e. with no extension on slow horizontal convergence encounters)
				INTEROP ALT	
One pilot does not follow the RAs					
Risk Ratio in Überlingen-like encounters	To be safer (from a statistical point of view)	At least a minor improvement	Minor = at least -5%)	Overall	-53% (-3.1)
				ALT	Decrease in all altitude bands
				INTEROP	-24% (-1.4)
				INTEROP ALT	Decrease in all altitude bands
Risk Ratio in EE encounters when one pilot does not follow the RAs	To be safer (from a statistical point of view)	At least a minor improvement	Minor = at least -5%	Overall	-52% (-8.0)
				ALT	Decrease in all altitude bands
				INTEROP	-24% (-3.6)
				INTEROP ALT	Decrease in all altitude bands
P1 Operational metrics					
Pilots follow the RAs					
Overall airspace					
RA alert rate (aircraft & encounter perspective)	Statistically assured improvement for operational acceptance (pilot & ANSP perspective)	At least a minor improvement	Minor = at least -5%	Overall	Reduction for aircraft and encounters perspective
Single 1,000ft LO subset					
RA alert rate in single 1,000ft LO encounters (aircraft & encounter perspective)	To be significantly fewer (from a statistical point of view) to improve compatibility with ATC and avoid disruption to pilots	At least a minor improvement	Minor = at least -5%	Overall	Reduction with PASS but increase with the radar data
				INTEROP	Reduction with PASS but increase with the radar data
Climb / Descend RA alert rate on-board the level aircraft in single 1,000ft LO encounters (aircraft perspective)	To favour RAs on-board climbing / descending aircraft rather than on the level aircraft (i.e. to not reintroduce the Dallas bump-up issue)	Not more than a minor increase	Minor increase = maximum +5%* *(*threshold to be discussed with a wider operational community)*	Overall	-73% (-27)
				INTEROP	-30% (-11)

More detail can be found in the following pdf documents encapsulating extracts from a mindmap:

T04.01a_ACAS Xa Run15 verification m

T04.01a_ACAS Xa Run15 verification m

2. Priority 2 metrics

The following table provides the results for priority 2 safety and operational performance metric.

Metric	Rationale	Qualitative Threshold	Guidance Value	Scope	Results
Overall airspace					
Pilots follow the RAs					
Risk Ratio in multi-aircraft encounters	To be at least as safe	At least no increase	/	**Overall**	**Not assessed**
RA alert rate in encounters with large horizontal separation (encounter perspective)	To keep the same level of compatibility with ATC and avoid disruption to pilots by triggering operationally unnecessary RA alerts	At least no increase (in number)	/	**Overall**	**-81% (-261)**
Rate of encounters with high vertical deviations	To keep the same level of compatibility with ATC and reduce the likelihood of induced conflicts with a third aircraft by triggering RAs requiring unnecessary high vertical deviations	At least no increase (in number)	/	**Overall**	**+93% (244) of deviations > 300ft** **+292% (70) of deviations > 600ft**
Reverse RA alert rate (aircraft perspective)	To favour the resolution of encounters which does not involve reversing the initial RA sense (e.g. robustness to uncertainty of response to these secondary RAs)	At least no increase (in number)	/	**Overall**	**-46% (-3959)**
Crossing RA alert rate (aircraft perspective)	To favour the resolution of encounters which does not involve a crossing in altitude (e.g. robustness to uncertainty of vertical tracker)	At least no increase overall & at least no increase in Crossing LOLO RAs (in number)	/	**Overall**	**Same as TCAS**
Strengthening RA sequence alert rate (aircraft perspective)	To favour the direct triggering of the appropriate RA	At least no increase (in number)	/	**Overall**	**+9% (4676)**
Very complex RA sequence alert rate (aircraft perspective)	Confidence in the system	At least no increase (in number)	/	**Overall**	**+3% (130)**
Time between TA and initial RA	For the flight crew to have appropriate time to prepare to the RA	Fewer RAs are triggered less than 6s after the TA	/	**Overall**	**+214% (120)**
Time between initial and secondary RA	Confidence in the system (i.e. wait for pilot to respond to the initial RA before triggering a secondary RA)	Fewer secondary RAs are triggered less than 3s after the initial RA	/	**Overall**	**-75% (-70)**
Early Clear of Conflict alert rate (aircraft perspective)	Confidence in the system (i.e. wait for aircraft to be in horizontal divergence to trigger a Clear of Conflict)	At least no increase (in number)	/	**Overall**	**-97% (-734)**
Split RA sequence alert rate	Confidence in the system	At least no increase (in number)	/	**Overall**	**-91% (-83)**
EE subset					

Metric	Rationale	Qualitative Threshold	Guidance Value	Scope	Results
Pilots follow the RAs					
Crossing RA alert rate in EE encounters (encounter perspective)	To favour the resolution of encounters which do not involve a crossing in altitude (e.g. robustness to uncertainty of vertical tracker)	At least no increase overall & at least no increase in asymmetrical Crossing RA alert rate (in number)	/	**Overall**	**+58% (1581)**
				INTEROP	**+44% (1210)**
Reverse RA alert rate in EE encounters (encounter perspective)	To favour the resolution of encounters which does not involve reversing the initial RA sense (e.g. robustness to uncertainty of response to these secondary RAs)	At least no increase overall & at least no increase in unnecessary Reverse RA alert rate (in number)	/	**Overall**	**-60% (-422)**
				INTEROP	**+24% (168)**
Reverse Crossing RA alert rate in EE encounters (encounter perspective)	Robustness to uncertainty of response to Reverse Crossing RAs	Some increase tolerated in Reverse Crossing RA alert rate but Reverse Crossing RAs should be avoided when aircraft are largely apart at the time of the Reverse Crossing RA	Largely = More than 300ft *(only 150ft allowed with TCAS II)*	**Overall**	**+685% (20824)**
				INTEROP	**+325% (9883)**
Überlingen-like subset					
One pilot does not follow the RAs					
Efficient Reverse RA alert rate in Überlingen-like encounters (encounter perspective)	In Überlingen-like encounters a Reverse RA must resolve the NMAC	Reverse RAs are at least as efficient	*(98% efficiency of Reverse RAs with TCAS II)*	**Overall**	**98.6%**
				INTEROP	**97.8%**
Rate of RA sequences with more than one Reverse RA on-board the same aircraft in Überlingen-like encounters (aircraft perspective)	Confidence in the system	At least no increase	/	**Overall**	**+58% (22)**
				INTEROP	**+109% (416)**
1,000ft level-off subset					
Pilots follow the RAs					
Single 1,000ft LO subset					
Climb / Descend RA alert rate on-board descending / climbing aircraft in single 1,000ft LO encounters (aircraft perspective)	To favour LOLO RAs rather than Climb / Descend RAs (i.e. to limit deviations from the current aircraft clearances)	At least no increase (in number)	/	**Overall**	**No cases with TCAS II and ACAS Xa**
RA alert rate on-board aircraft climbing / descending below 1,500fpm in single 1,000ft LO encounters	To avoid triggering RAs when ICAO recommendation on "high vertical rate (hvr) encounters" is followed (refer to ICAO doc)	At least no increase (in number)	/	**Overall**	**+1088% (87)**

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Metric	Rationale	Qualitative Threshold	Guidance Value	Scope	Results
(aircraft perspective)					
Double 1,000ft LO subset					
RA alert rate in double 1,000ft LO encounters (encounter perspective)	To improve compatibility with ATC and avoid disruption to pilots by triggering operationally unnecessary RAs	At least no increase	/	**Overall**	**-27% (-192)**
				INTEROP	**-4% (-27)**
Climb / Descend RA alert rate in double 1,000ft LO encounters (aircraft & encounter perspective)	To favour LOLO RAs rather than Climb Descend RAs (i.e. to limit deviations from the current aircraft clearances)	At least no increase (in number)	/	**Overall**	**Aircraft: -99% (-584)** **Encounter: -99% (-422)**
				INTEROP	**Aircraft: -50% (-296)** **Encounter: -31% (-134)**

More detail can be found in the following pdf documents encapsulating extracts from a mindmap:

T04.01a_ACAS Xa Run15 verification m **T04.01a_ACAS Xa Run15 verification m**

B.2.3 Conclusions

Safety performance

The risk ratio is reduced compared to TCAS II v7.1 in almost all cases and the previous issues of risk degradation during the transition period (when ACAS Xa and TCAS coexist) have been resolved. However, the following risks remain:

- A limited increase in overall risk ratio above FL135 due to Equipped-Unequipped encounters;
- An enlarged number of very close encounters without corrective RAs (and even without any RA), but remaining in the relatively same triggering envelope than TCAS II

A secondary concern is the increased occurrence of stressful RAs:

- More Increase RAs with ACAS Xa, that if not followed increases the risk ratio by about 30%;
- More Crossing RAs and very complex RA sequences with ACAS Xa on EE safety encounters;
- More Reverse RAs, asymmetric Crossing RAs and multiple Reverse RAs (up to 3, especially on Überlingen-like encounters) in mixed TCAS II and ACAS Xa environment
- On Überlingen-like encounters, 60% of ACAS Xa Reverse RAs are Crossing RAs and 25% of ACAS Xa Reverse Crossing RAs are triggered when aircraft are more than 300ft apart (vs. 0% with TCAS II, since unauthorized above 150ft with TCAS II)

The reason why this is a concern is that stressful RAs are more likely not to be followed adequately by the flight crew. ACAS Xa safety performance improvement compared to TCAS II seems largely relying on the issuance of stressful RAs. One way to remove this concern and ensure ACAS Xa full benefits would be to mandate the automatic response to ACAS Xa RAs by the flight guidance system when the AP is engaged (a SESAR 1 solution).

Human performance

The RA alert rate is greatly reduced compared to TCAS II v7.1 in almost all cases and it occurs linearly through ACAS Xa deployment. The triggering pattern is not the same for ACAS Xa and TCAS II v7.1, which results in some increase / decrease in RA triggering in some specific geometries:

- In 1,000ft single Level-Off encounters, ACAS Xa significantly removes RAs during encounters with vertical speed > 1500fpm but significantly adds RAs during encounters with vertical speed < 1500fpm;
- In 1,000ft double Level-Off encounters, ACAS Xa significantly removes Climb and Descend RAs;
- In 1,000ft Jump encounters, ACAS Xa triggers more undesired RAs (e.g. additional Maintain RAs triggered with ACAS Xa after aircraft vertical crossing) resulting in altitude overshoot and large deviations;
- In 500ft level-level encounters, ACAS Xa removes almost all preventive RAs.

There are also less RAs with a large horizontal separation.

However, the concern of more situations with high vertical deviations remains. They are caused by ACAS Xa issuing weakening RAs later than TCAS II v7.1. This is a concern because these deviations may disturb ATC planning.

A concern for pilot acceptability is the increased issuance of RAs close to the TA, meaning that the TA cannot fulfil its role of cueing visual acquisition and preparing to an RA.

Overall conclusion

It has been noted that ACAS Xa behaviour is difficult to understand on some particular encounters due to its probabilistic approach (vs. TCAS II deterministic approach).

The concerns and risks mentioned above will have to be weighed by EASA against the benefits of the system and the European constraints in order to decide on the acceptability of ACAS Xa in Europe.

B.3 Impact on the V3 VALR consolidated sections

Any mention of limitations of representativeness, realism and result quality concern is no longer valid after the rerun of EXE-05 reported in this appendix.

The validation results and success criteria status in the summary table of section 4.1 are replaced by those in section B.2.1 of this document for the success criteria under OBJ-11.A1-V3-VALP-002 and OBJ-11.A1-V3-VALP-003.

The conclusions on Safety performance in section 5.1.4 regarding the TRM performance are replaced by those in section B.2.3 of this document. The conclusions on Human performance in section 5.1.4 regarding the TRM performance are replaced by those in section B.2.3 of this document, except the part covering the compatibility of Run 15.4 with the SESAR 1 TCAP feature.

Recommendation 5, regarding the need for a second verification of ACAS Xa Run 15.4 is now obsolete. A new recommendation could be added for the deployment phase:

x. European safety authorities should mandate the use of an automatic response to RAs for aircraft equipping with ACAS Xa