Final Project Report

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Abstract

Project SESAR 9.47 - TCAS Evolution - aimed at defining and assessing feasibility of ACAS evolutions required to support aircraft operations in the future SESAR environment. In this context it addressed the benefits associated with the implementation of extended hybrid surveillance capability into TCAS II in terms of reduced use of 1090 MHz frequency; development and validation of surveillance functions for a new generation of ACAS, referred as ACAS X; and performance study of new traffic awareness for collision avoidance systems designed for general aviation.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted], Honeywell	[redacted]	02/09/2016

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] Honeywell	[redacted]	30/08/2016
The document was sent for final review to all project members. No comments were received.		

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
This document was provided for final review to OFA Coordinator and WPL. No comments were received.		

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] Honeywell	[redacted]	30/08/2016
[redacted], DSNA		02/09/2016
[redacted] EUROCONTROL		02/09/2016
[redacted] Airbus		02/09/2016

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ACAS	Airborne Collision Avoidance System
ACAS X	Next Generation Collision Avoidance System
ACAS Xa	ACAS X - Active
ACAS Xp	ACAS X - Passive
ADS-B	Airborne Dependent Surveillance - Broadcast
ANSP	Air Navigation Service Providers
ATM	Air Traffic Management
CAT	Commercial Air Transport
FAA	Federal Aviation Administration
GA	General Aviation
MOPS	Minimum Operational Performance Standards
RA	Resolution Advisory
RF	Radio Frequency
RPAS	Remotely Piloted Aircraft Systems
RTCA	Radio Technical Commission for Aeronautics
SC	Special Committee (RTCA)
STM	Surveillance and Tracking Module
TCAS	Traffic Alert and Collision Avoidance System
TRM	Threat Resolution Module
TSAA	Traffic Situational Awareness with Alerts
TSO	Technical Standard Order
VALP	Validation Plan
VALR	Validation Report

1 Project Overview

Project SESAR 9.47 aimed at defining and assessing feasibility of Airborne Collision Avoidance System (ACAS) evolutions required to support aircraft operations in the future SESAR environment. In this context it addressed:

- The benefits associated with the implementation of extended hybrid surveillance capability into Traffic Collision Avoidance System (TCAS) II in terms of the reduced use of 1090 MHz frequency;
- Development and validation of surveillance functions for the new generation of ACAS, referred as ACAS X (in particular its active variant ACAS Xa);
- Support of the validation activities of ACAS Xa within the project SESAR 4.8.1.
- Performance study of new traffic situation awareness and collision avoidance systems designed for general aviation.

1.1 Project progress and contribution to the Master Plan

Project SESAR 9.47 execution was divided into three areas:

Extended hybrid surveillance

Hybrid and extended hybrid surveillance are TCAS II capabilities allowing tracking distant intruders using data from their Airborne Dependent Surveillance - Broadcast (ADS-B) reports, and thus considerably reduce the use of 1090 MHz. A baseline for the development and validation of TCAS II with extended hybrid surveillance capability was the definition of performance objectives and functional requirements. Consequently, an experimental platform with this capability was developed and validated. The validation performed within the project was the first worldwide flight test validation of this capability, and was conducted in three steps:

- Firstly, a Honeywell-developed prototype was installed at Airbus lab with roof-top antenna installation in proximity of Toulouse airport tracking the traffic in this area (2014) proving seamless basic functionality;
- Secondly, the prototype was installed in Airbus A320 experimental aircraft performing flight in proximity of Toulouse airport in both low and high altitudes (2014 and 2015), resulting in preliminary estimation of RF load reduction by approximately 71%.
- And last step was a fast-time benefit simulation by EUROCONTROL, assessing overall impact on 1090 MHz RF load in core European airspace (2015). This simulation confirmed preliminary estimated savings on RF load.

Additionally, complementary flights performed by Honeywell B757 in core European airspace (2016) showed interrogation reduction by up to 86.5%.

Extended hybrid surveillance capability is SESAR Technological Solution (#101) that completed TRL6 as part of the Release 5.

ACAS Xa

ACAS Xa concept, currently under definition within RTCA SC-147/ EUCOCAE WG-75, is being developed, optimized and validated through issuance of progressive versions of a collision avoidance system called "Runs". Project activities in this area consisted in continuous development of experimental platform, and fast-time simulation model allowing iterative evaluations of the system performance with focus given on surveillance functions.

Three validations were performed within the scope of the project, with feedback being provided to standardization after each of them. Each validation was concluded by an update of surveillance technical specifications. Honeywell-developed experimental platform supported FAA ACAS Xa Run13 flight tests in 2015, and European Run14 real environment roof-top validation, as well as human-in-the-loop validation performed by DSNA and Airbus within SESAR 4.8.1 in 2016.

Collision avoidance for general aviation (GA) activities

The goal of work performed on this topic was to analyse the state-of-art in the area of passive situation awareness concepts for GA. In the first step, initial proposition for performance comparison of GA-intended version of ACAS X (ACAS Xp) and Traffic Situational Awareness with Alerts (TSAA) systems was defined in 2014, followed by comparison of the two systems itself. Aim of the document was to indicate points that should be considered for further ACAS Xp system definition and development, in particular how big are the differences resulting from the fact that ACAS Xa logic is tuned for Commercial Air Transport (CAT) operations with different performance characteristics.

Project contribution summary

The following table presents project contribution to OI Step as defined by DS15. This OI step is going to be split in DS16, to address four collision avoidance solutions for different types of aircraft operations. Based on that, the ACAS Xa work will refer to CM-0808a (Improved collision avoidance for commercial air transport in normal operations), and GA related work will refer to CM-0808p (Collision avoidance for GA and rotorcraft). Moreover, a change request was issued for the refinement of A/C-54a enabler, to identify enabler that is covering specifically enhanced hybrid surveillance standardized in DO-300A/ED-221. The change request for this enabler, with proposed name A/C-54rai (Enhanced Airborne Collision Avoidance System with reduced active interrogations) was rejected for DS16, but should be re-opened or re-created for DS17.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
CM-0808 & enabler: A/C-54a	Enhanced Airborne Collision Avoidance adapted to trajectory based operations	Extended hybrid surveillance: Development of functional requirements for the use of extended hybrid surveillance in Europe. Prototype development, and its validation - first worldwide flight testing of this capability and benefit analysis bringing about promising results.	TRL3	TRL6
		ACAS Xa: Continuous evaluation of the ACAS Xa surveillance functions. Development of ACAS Xa prototype used for FAA ACAS Xa flight testing, as well as European roof-top validation, and human-in-the-loop validation performed within SESAR 4.8.1. Support to RTCA SC-147/ EUROCAE WG-75 standardization groups by providing feedback from performed validations in Europe.	TRL1	TRL4
		Collision avoidance for GA: Recommendations for future ACAS Xp development based on the comparison of the performance of GA-intended TSAA system and the relevant alerting capabilities with ACAS Xa.	TRL1	TRL2

1.2 Project achievements

Extended hybrid surveillance achievements

One of the most significant achievements of the project is the first worldwide flight testing of TCAS II with extended hybrid surveillance capability using the Honeywell prototype implemented according to DO-300A / ED-221, integrated into Airbus A320 testing aircraft. The validation consisting of three exercises confirmed that the system behaved according the expectations and fulfilled the intended function. Only a few minor technical comments related to Minimum Operational Performance Standards (MOPS) were communicated to the standardization working group. Preliminary benefits evaluation, showing the reduction of Mode S interrogations by more than 71%, was complemented by evaluation of overall impact of TCAS II with extended hybrid surveillance capability on 1090 MHz RF load in core European airspace performed by EUROCONTROL. This evaluation confirmed the expected benefits of the capability, and showed that the reduction of 1090 MHz rate can be as high as 89% if TCAS II is replaced by TCAS II with such capability for all TCAS II equipped aircraft, and all Mode S aircraft are emitting ADS-B level 2 (in line with European Commission Implementing Regulation). Additional flight test data collected in 2015 also confirmed the preliminary benefits, and refined analysis taking into account additional factors showed approximately 83% savings on TCAS II usage of 1090 MHz. Moreover, complementary flights performed by Honeywell B757 in core European airspace (2016) showed interrogation reduction by 86.5%.

TCAS II with extended hybrid surveillance capability is SESAR Release 5 Technological Solution #101, with TRL6 completed. This technology is already required by FAA, in the current version of Technical Standard Order (TSO), i.e. TSO-C119d. Results indicate that extended hybrid surveillance is a very promising and important tool for reduction of 1090 MHz overload.

ACAS Xa achievements

ACAS Xa related achievements can be summarized as follows:

- ACAS Xa prototype (Run13) developed within the project successfully supported FAA flight testing in 2015 with positive feedback to surveillance functions of the system. Updated prototype (Run14) was provided for SESAR 4.8.1 human-in-the-loop evaluation in 2016, and first European real-environment evaluation, when ACAS Xa prototype was installed at Airbus lab in Toulouse using roof-top antenna installation for intruders tracking.
- ACAS Xa Surveillance and tracking model (STM) fast-time simulation platform, and surveillance error model were developed to support the performance evaluations.
- The results from Run13 and Run14 evaluations provided valuable feedback to standardization, pointing out the overconfidence of horizontal passive tracking algorithm of the system.
- Surveillance technical specifications for ACAS Xa were defined, and iteratively updated after each validation phase, providing set of up-to date requirements at the end of the project.

The prototype, fast-time simulation models, and technical specifications are expected to be continuously updated and used for follow up activities under SESAR2020.

Collision avoidance for GA achievements

Comparison study of TSAA and ACAS X identified the importance of GA specific operational acceptability to be taken into account for further ACAS Xp definition and development.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D01	Feedback on proposed TCAS changes	This document provided a preliminary assessment of the system impact for two TCAS II improvements proposed within SESAR 4.8.2 project: reduced resolution advisory (RA) thresholds, and use of ADS-B data in horizontal miss distance filter. Both proposed changes aimed to reduce number of nuisance RAs, and thus to increase the performance of the current TCAS II system while maintaining at least the same level of safety. Both proposed changes differed considerably in their complexity and the achieved maturity of their validation. Taking into account lack of effort, budget, time limitations, and the ongoing intensive ACAS-X research activities, SESAR 4.8.2 project team recommended not to continue with research in this area.
D10	Performance objectives and functional requirements for the use of improved hybrid surveillance in European environment	This document provided a description of the proposed TCAS enhancements in terms of functional requirements, and was used as a baseline for development and validation of improved hybrid surveillance capabilities in the SESAR 9.47 project. In addition, an analysis of potential operational impacts of wrong ADS-B data on TCAS performance was analysed through encounter-based methodology.
D12	V&V plan for improved hybrid surveillance	The objective of extended hybrid surveillance is to profit from widespread deployment of ADS-B Out technology in order to considerably reduce the use of overburdened 1090 MHz frequency by TCAS (triggering of Mode S replies through TCAS interrogations). This document described planned validation activities of this new TCAS II capability using the system standard which was developed in the frame of the SESAR 9.47 project. Validation activities for extended hybrid surveillance within the scope of this project are focusing on two main areas: To validate and quantify the benefits achievable in real European environment and to support standardization work by validating assumptions adopted during the definition phase and within the system requirements development.
D32	Report on improved hybrid surveillance validation (issue2)	This validation report concludes all SESAR 9.47 validation activities of TCAS II with extended hybrid surveillance capability, as well as provides feedback to the standardization activities on the extended hybrid surveillance MOPS. Focus was given on overall benefit analysis and behaviour in all conditions: on ground, in the air and during take-off and landing. This report describes first worldwide validation of this capability with real industrial system in real environment including flight testing. Benefits evaluation showed approximately 83% savings of TCAS II 1090 MHz usage.

D14	Operational requirements assumptions and scenarios for GA	With the upcoming mandates of ADS-B Out, ADS-B surveillance enables far better means to develop airborne surveillance and collision avoiding systems for GA. The two new applications targeting GA that are currently being developed in parallel: TSAA and ACAS Xp are discussed within this document, together with a proposition for performance comparison of both systems. An expected output of the proposed assessment would provide a clearer idea of differences in alerting of the two systems (timing, encounter configuration impact, etc.) and therefore of potential impact on the GA operations.
D15	Comparison study of TSAA and ACAS Xp performance	This study compared the performance of GA-intended TSAA system and its alerting capabilities with ACAS Xa (primarily addressing CAT needs) model modified to use passive surveillance only; however without any modifications for GA. Selected TSAA-tailored MOPS test vectors were run through both TSAA and ACAS X models. The main aim of this document is to indicate points that should be taken into account for further ACAS Xp system definition and development, in particular how big the differences resulting from the fact that ACAS Xa logic is tuned for CAT operations and different a/c performance characteristics are.
D17	Support to standardization activities report	This document summarizes the scope of RTCA SC-147/EUROCAE WG-75 and describes the standardization activities performed by SESAR 9.47 members for the standardization subgroup. The objective of this document was to make a high level status on where standardization groups stand currently; and to summarize the inputs made by SESAR 9.47 to those groups, and the outputs from those groups to SESAR 9.47.
D21	VALR from initial STM performance evaluation	This document describes the results of detailed performance evaluation of the surveillance functions designed within ACAS Xa. Performed study shows a good performance of the ACAS Xa surveillance functions in the estimation of the most probable position of intruders for both types of used surveillance techniques (Mode S interrogation and ADS-B). Nevertheless, obtained results indicate that the confidence area is too optimistic (narrow) for description of the true intruder's position. The results also show that despite very different sizes and shapes of the confidence intervals for different surveillance methods the probabilistic estimation of time to the conflict does not differ considerably.
D22	VALR from integrated TRM+STM performance evaluation.	This document describes the results of the sensitivity study of the performance of ACAS Xa Run 13 (in European environment) to surveillance errors considering both STM and Threat Resolution Module (TRM) modules. This study shows degradation on safety performance when using

		passive data in addition to active data, and when decreasing the update interval rate for passive data. In general, the results obtained are not intuitive; a similar analysis should be performed on the latest version of the STM to check the trends of the results.
D25	Technical lessons learned (FAA 2015 flight tests)	This document describes the second round of evaluation of new generation ACAS, referred to as ACAS Xa, where Run13 STM processed surveillance data recorded during 2015 FAA flight tests. Performed analysis confirms a good performance of the ACAS Xa surveillance functions in the estimation of the most probable position of intruders for both types of used surveillance techniques (Mode S interrogation and ADS-B). Nevertheless, results show that the confidence areas defined by the tracker were too narrow corresponding to ~76% probabilistic level (comparing to expected 95%). The results of the verification show that the approach applied in previous study was sufficiently adequate.
D28	VALR from ACAS Xa technical validation	This document provides the validation report for the second and last phase of ACAS Xa validation within SESAR 9.47 project. The validation was performed in real European environment, with ACAS Xa Run14 experimental platform tracking real traffic in the proximity of Toulouse airport via fixed roof-top antenna installation. In addition, roof-top recorded data were provided on the input to Run13 model to assess the difference in performance between the two Runs.
D29	STM specifications - issue 3	The purpose of this document is to summarize an up-to-date status of ACAS-X surveillance requirements, definitions, and assumptions, together with a list of identified open points and gaps. This version is the second update of technical specifications that were delivered within SESAR 9.47 project, as deliverable D19 and D24. The update of document was performed based on Run 13 FAA flight test data analysis and Run14 roof-top validation results.

1.4 Contribution to Standardisation

The results of the project were contributing to RTCA SC-147 / EUROCAE WG-75 standardization work. Extended hybrid surveillance outputs supported development of DO-300A / ED-221 standard, and ACAS Xa evaluations results are regularly presented and shared with standardization groups, together with final validation reports in order to support future development of ACAS Xa MOPS, which is planned to be published in 2018.

During the project duration, 23 presentations in total were given at RTCA SC-147/ EUROCAE WG-75 face-to-face meetings or teleconferences by the project members. These were mainly supporting the

standardization by active participation on the meetings, iterative evaluations of proposed solutions, proposing the changes to existing standards, contribution to system interface requirements, presenting obtained results and providing feedback, reviewing of the working documents, providing comments and contributing to MOPS development, and last but not least, providing system manufacturer / ANSP / aircraft manufacturer point-of-view to different discussions.

1.5 Project Conclusion and Recommendations

Achieved results conclude that project successfully fulfilled its objectives, and supported ATM Master Plan goals by contributing on the significant progress of OI Step named Enhanced Airborne Collision Avoidance adapted to Trajectory based operations.

The success of the project can be materialized by:

- The production of one SESAR technological solution: extended hybrid surveillance.
- Successful delivery and validation of two prototypes: TCAS II with extended hybrid surveillance capability (V3 maturity level), and ACAS Xa (V2 maturity level).
- Significant contribution to the development of the new ACAS system, with a focus on surveillance functions.

To maximize the effect of results achieved in the project, it is recommended to:

- Promote and disseminate benefits of extended hybrid surveillance solution as very promising and important tool for reduction of 1090 MHz RF overload.
- Authorities, to take implementation of extended hybrid surveillance capability into account when formulating the RF load reduction strategy.
- Continue in validation activities of consecutive ACAS Xa runs, primarily in European airspace, and support the MOPS development.
- Development of collision avoidance system tailored for new airspace users (ACAS Xu for RPAS, and ACAS Xp for GA)
    - Define operational acceptability criteria for these users.
    - Investigate the impact of performance characteristics on alerting logic.

2 References

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