Final Project Report

Document information	
Project Title	Enhanced safety nets for en-route & TMA operations
Project Number	04.08.01
Project Manager	DSNA
Deliverable Name	Final Project Report
Deliverable ID	D000
Edition	00.01.02
Template Version	03.00.04
Task contributors	
DSNA	

Abstract

Project 04.08.01, "Enhanced safety nets for en-route & TMA operations", aimed at conducting the appropriate evolution of en-route and TMA safety nets to ensure that they will continue to play an important role as a last safety layer against the risk of collision (and other hazards) during future operations.

This Final Project Report is a summary of the project's goals and achievements and highlights the link between the project activities and the SESAR outcomes.

2 Authoring & Approval

Prepared By – *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] DSNA		12/05/2016
[redacted] DSNA (Egis Avia)		12/05/2015

3

Reviewed By – *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
(The document was sent for final review to all project members. Only answers from the members below were received)		
[redacted] Indra		03/05/2016
[redacted] DFS		03/05/2016
[redacted] Selex		09/05/2016
[redacted] DFS		10/05/2016
[redacted] Eurocontrol		10/05/2016
[redacted] NATS		10/05/2016

4

Reviewed By – *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted] DSNA (Egis Avia)		03/05/2016

5

Approved for submission to the SJU By – *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] DSNA		03/05/2016
[redacted] DFS		10/05/2016
[redacted] DSNA		10/05/2016
[redacted] ENAV		10/05/2016
[redacted] Eurocontrol		10/05/2016
[redacted] Indra		04/05/2016
[redacted] NATS		10/05/2016
[redacted] Selex		09/05/2016

6

Rejected By – *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
Not applicable		

7
8

Rational for rejection
Not applicable

9 Document History

Edition	Date	Status	Author	Justification
00.00.01	12/05/2015	Draft		New Document

00.01.00	03/05/2016	Revised Draft		Change of template; completion of all sections
00.01.01	12/05/2016	Final Draft		Review by partners before submission to SJU
00.01.02	15/05/2016	Final Draft		Clarifications requested in SJU assessment

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ACAS	Airborne Collision Avoidance System
ADS-B	Airborne Dependent Surveillance – Broadcast
ADS-C	Airborne Dependent Surveillance – Contract
AP	Auto-Pilot
A-SNET	Airborne Safety NET
APM	Approach Path Monitor
APW	Area Proximity Warning
CFL	Cleared Flight Level
DAP	Down-linked Aircraft Parameters
EASA	European Aviation Safety Agency
FAA	Federal Aviation Administration
FMS	Flight Management System
EHS	Enhanced Surveillance (Mode S)
G-SNET	Ground-based Safety NET
IBP	Industry-Based Platform
MoC	Memorandum of Cooperation
MSAW	Minimum Safe Altitude Warning System
NMAC	Near Mid-Air Collision
OSED	Operational Services and Environment Definition
PCP	Pilot Common Project
SFL	Selected Flight Level
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SNET	Safety NET
STCA	Short-Term Conflict Alert
SWIM	System-Wide Information Management

TAR	Turn Angle Rate
TCAS	Traffic alert and Collision Avoidance System
TMA	TerMinal control Area
SPR	Safety and Performance Requirements
VALP	Validation Plan
VALR	Validation Report

1 Project Overview

The project developed solutions aimed at improving the operations of safety nets (SNETs) that are used in terminal control area (TMA) and en-route airspaces, whether they are ground-based (G-SNETs) or airborne (A-SNETs), and ensuring that they are adapted to the new operational environments developed within SESAR. The project addressed all G-SNETs: Short Term Conflict Alert (STCA), Minimum Safe Altitude Warning (MSAW), Area Proximity Warning (APW) and Approach Path Monitor (APM). The project only addressed one A-SNET: Airborne Collision Avoidance System (ACAS).

1.1 Project progress and contribution to the Master Plan

In order to progress in the development of its solutions, the project applied the E-OCVM methodology and cooperated with the technical mirror projects, in charge of the development of technical specifications and of providing prototypes. However, there are differences in the way G-SNET solutions and A-SNET solutions were validated, which are described below:

Development of G-SNET related solutions

One of the solutions (#60) only used already available ground data and consisted in generalizing an already existing improvement. In this case, the validation consisted in fast-time simulations of real radar data of the target environment on an Industry-Based Platform (IBP) including a prototype provided by the technical mirror project (10.04.03) and subsequent classification of resulting alerts by expert judgment. Then the results were compared to the existing system.

For the other solutions which involved providing air data (EnHanced Surveillance (EHS) Downlinked Aircraft Parameters (DAPs), then ADS-B DAPs) to the G-SNET, the first step consisted in identifying what would be the possible uses of the available (current and future, mandated or not) data in each G-SNET.

The second step consisted in assessing each option. The quality of the data was one factor and for EHS data, it was possible to quantify it on real radar recordings. Another factor was the possible benefits brought by the option. Except for STCA where fast-time simulations on a large set of encounters allowed quantifying the possible benefits of some options[1], the benefits of other options[2] for STCA and other G-SNETs[3] were qualitatively estimated by data mining and expert judgement. Finally, the costs of implementation were also estimated by expert judgement, based on past implementations in the field of G-SNETs.

Once the most promising options were identified, the next step consisted in developing them. It was possible to do it for EHS data: a prototype of STCA using two DAPs and provided by the technical mirror project (10.04.03) was used in the target environment, first in fast-time simulations based on real radar data, then in human-in-the-loop real time simulations. It was not possible to evaluate the use of ADS-B data due to insufficient maturity of additional ADS-B / ADS-C trajectory data potentially of use for STCA and unavailability or limited usability of available results (from other primary projects) on the future "trajectory-based" environments identified as relevant for G-SNET evolution (i.e. Free Routing, Airspace Management & AFUA, Conflict Detection Resolution & Monitoring, Enhanced Decision Support Tools & PBN, Dynamic sectorisation and Constraint management).

Development of ACAS-related solutions

Where the solution covered airside improvements, the validation work was mainly done in fast-time simulations on a large set of close encounters. This set was either generated from encounter models that statistically represent the European operational reality or from radar data where specific situations could be selected. The realism was judged as sufficiently high by the technical mirror project (09.47) to allow reaching maturity V3.

[1] Use of EHS MCP/FCU Selected Altitude, EHS Roll Angle and EHS Track Angle Rate
[2] Use of EHS Aircraft Identity, EHS Barometric Pressure Setting, EHS FMS Selected Altitude, ADS-B / ADS-C trajectory data, ADS-B trajectory type, SWIM airspace data
[3] All the uses mentioned in the two previous notes

Where the solution covered groundside improvements, the involvement of controllers was necessary, so fast-time simulations were only used to evaluate the timing of interaction between the ground-based safety-net (STCA) and ACAS. Afterwards, human-in-the-loop experiments were conducted using a mock-up developed by the project, and then using a prototype developed by the technical mirror project (10.04.03) and integrated in an IBP. However, as RA encounters are very rare in reality and their reproduction in real-time simulation is normally thwarted by controller intervention (supported by control tools and STCA), the simulation had to feature an unrealistic number of RAs and controllers could not act on the aircraft.

In both cases, the negative safety case was developed using expert judgement and with the help of workshops to characterize the safety hazards.

Using the methods and tools described above, the project was able to contribute to Operational Improvement steps from the ATM Master Plan (as of Data Set 15) as follows:

Code	Name	Project contribution	Maturity at project start	Maturity at project end
CM-0811	Enhanced STCA for TMA specific operations	The project developed requirements for better trajectory prediction, taking into account possible crew intents linked to traffic patterns and contributed to the operational validation, using Lyon TMA data, of a prototype STCA that included this feature.	V2	V3
CM-0807-A	Enhanced Short Term Conflict Alert using Mode S EHS data	The project assessed the feasibility, qualitative safety benefits and costs of using Mode S EHS data in STCA; After identifying the most promising options, requirements were produced and the project contributed to the integrated validation of the most promising option, STCA using Selected Flight Level and Track Angle Rate, both in recorded data and live simulations of Milano ACC.	V2	V3
CM-0807-B	Enhanced Ground-based Safety Nets Using ADS-B information	The project assessed the feasibility, qualitative safety benefits and costs of using ADS-B data in STCA, MSAW, APW, APM in the context of future operations estimated to have the most impact on these G-SNETs. The most promising options were identified (use in APW coming first). However no requirements were produced: the project decided to stop the concept development after V2 exercises which highlighted the lack of maturity of the concept due to lack of availability of Step 2 traffic patterns and of ADS-B data;	V0	Ongoing V2
CM-0803	Use of Autoflight systems for enhanced compliance with TCAS II RAs (compliant with TCAS II Version 7)	The project assessed the benefits of several options for better compliance to RAs and slower altitude capture before the CFL to avoid RAs. Requirements were produced which capture the best options for both features. The project then contributed to the standardisation of both features in a EUROCAE MASPS (ED-224).	V2	V3
CM-0802	Display and use of	The project developed operational	V1	Ongoing V3

	ACAS resolution advisory downlink on the controller working position	requirements for the technical system in charge of collecting and distributing RA information to ground systems. Two validations took place with increasing realism (mock-up then integrated validation with display prototype) and proved subjective benefits but could not select one of the two operational procedures proposed (mainly because of uncertainties on legal interpretations). As a consequence, only the technical enablers (CTE-S03g and ER-APP-ATC 68) are mature.		
CM-0808	Enhanced Airborne Collision Avoidance adapted to Trajectory based operations	The project developed operational requirements for an enhancement of current TCAS through optimized RA thresholds and assessed the benefits. This improvement was not progressed further as there was no support from the standardization groups to improve current TCAS. The project then switched to supporting the development of the solution chosen by FAA and the standardisation groups, a new ACAS developed from scratch. The project developed European requirements and European acceptability criteria for this system. Regular evaluation of the development version (until the previous to last version) allowed to feed FAA with identified areas of improvement for Europe.	V1	V2

Note that the project also assessed the feasibility, qualitative safety benefits and costs of using Mode S EHS data in other G-SNETs than STCA (MSAW, APM and APW), identifying the most promising options and producing requirements but those options were not validated further than V2.

As part of the Priority Business Need related to Conflict Management and Automation, the project delivered three SESAR solutions:

Sol ID	Sol Name	OI step(s)	Coverage	Supporting Enabler(s)
#60	Enhanced Short Term Conflict Alert (STCA) for Terminal Manoeuvring Areas (TMAs)	CM-0811	Full	APP ATC 136
#69	Enhanced STCA with down-linked parameters	CM-0807-A	Full	ER APP ATC 14 GSURV-0101 REG-0503
N/A	Enhanced ACAS operations using autoflight systems	CM-0803	Full	A/C-21 PRO-A/C-21

The project also contributed to the development projects 10.04.03 / 10.04.03 of the following SESAR technical solution:

Sol ID	Sol Name	Enabler(s)	Coverage	Supported OI step(s)

#100	ACAS Ground Monitoring and Display System	CTE-S03g ER-APP-ATC-68	Full	CM-0802

1.2 Project achievements

Results for STCA

The project allowed STCA to be used in at least low to medium density TMAs. Indeed, the project generalized an existing concept that avoids triggering an excessive number of unnecessary alerts in airspace with many aircraft trajectory changes, by taking into account several hypotheses: the classic linear extrapolation and additional non-linear extrapolations based on possible crew intents linked to traffic patterns and ATC practices.

The project also improved STCA performance through better trajectory prediction, taking into account additional non-linear extrapolations based on real crew intents, as reflected in SFL and TAR DAPs. This resulted in a reduction of unnecessary RAs by up to 26%, with increased warning times when it mattered.

Note that a reduction of unnecessary RA has an indirect positive effect on safety as controllers will not have to spend their time to process such an alert.

Results for all G-SNETs

The project identified other promising potential uses of EHS data in G-SNETS (aside from the SFL and TAR use in STCA) that could be assessed within SESAR 2020:

- Use of FMS Selected Altitude within STCA to cover the case when the target altitude is the FMS Altitude
- Use of Roll Angle and Track Angle Rate within APM to detect a turn earlier and model it more precisely;
- Use of Magnetic Heading within APM for a conformance check with runway magnetic heading

Likewise but in a context of trajectory-based operations, the project identified the most promising potential uses of ADS-B and SWIM data in G-SNETS that could be assessed within SESAR 2020:

- trajectory data to improve trajectory prediction (in STCA and APW);
- trajectory data to provide Resolution Advisories to air traffic controllers (in STCA);
- trajectory data to determine eligibility of aircraft for safety net protection (in APW);
- trajectory data to determine safety net parameters for alert generation (in STCA);
- SWIM airspace data to accommodate dynamic airspace configuration (in APW);
- SWIM airspace data to accommodate Advanced Flexible Use of Airspace (in APW);
- trajectory data to alert military aircraft excursions from danger/restricted areas (in APW);

Results for ACAS

The project confirmed that displaying RAs on the controller working position increases controller's situational awareness, and that the technical system produced by projects 10.04.03 and 10.04.03 ("ACAS ground monitoring and display system") provide timely and useful RA information for use by the controller. Two operational procedures for this use were proposed a way forward to select one of them was produced.

The project improved ACAS operations by determining how to best exploit the coupling of ACAS with auto-flight systems. The benefit in safety of allowing an automatic response to RAs by the autopilot can be as high as 30% less NMAC per flight-hour compared to manual response, if no pilot disconnects the AP. The benefit for in human performance of applying a TA-triggered new altitude capture law that reduces vertical speed when close to the CFL is measured by a reduction of the number of unnecessary RAs by a factor of at least 30. These features were a generalization for all aircraft of concepts developed by Airbus. Since their validation, Airbus has certified them on most of its aircraft series and can also provide access to it patents with reasonable conditions.

The project improved ACAS performance by optimizing current ACAS triggering thresholds, thus dividing the number of unnecessary RAs by around 3 compared to current ACAS, while preserving the same level of protection against collisions. As of now, current ACAS is not planned to be changed, but this improvement can be seen as a backup if needed.

The project contributed to the development of the new ACAS, initiated by FAA, which features mathematically optimized RAs, use of ADS-B data and a more flexible development process than TCAS. Good working relationships were established with FAA under the framework of Coordination Plan 4.1 of the FAA/SJU MoC. Anticipated benefits of ACAS Xa are significant (e.g. around 35% decrease in risk in the latest version) but have to be confirmed in SESAR 2020. A list of criteria for European acceptability has been developed, to be used as benchmarks in validations and possibly by EASA before accepting ACAS Xa introduction in Europe.

Other results

The project supported the development of direct routing (AOM-500) and of the initial stage of free routing (AOM-501) regarding the effects of the concept on STCA. Both concepts are within the scope of the PCP.

1.3 Project Deliverables

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

Reference	Title	Description
	Key deliverables for CM-0811 – Solution #60	
4.8.1-D03	SPR-STCA-V2 Consolidated baseline framework for safety and performance	This SPR describes a consolidated framework for safety assurance and performance evaluation of STCA. Eurocontrol operational requirements for STCA are updated with TCAS interoperability requirements from the Eurocontrol sponsored project PASS. Quantitative safety requirements are generic and will need instantiating for a particular airspace. A summary of the associated safety assessment is included to support the safety requirements. Common quantitative performance requirements are not considered mature enough at this stage. Excerpts from the PASS final project report and dissemination workshop are included as an example of applying a similar framework to a specific airspace model to derive quantitative safety and performance requirements, and as an indication of current maturity.
4.8.1-D05	VR-TMA-STCA-V3 Operational evaluation of industrial STCA	This V3 VALR describes the validation of an enhanced STCA for TMA based on an industrial prototype developed

	prototype for TMA	in the scope of SESAR. The prototype is configured for one TMA (i.e. Lyon in France), run in fast-time with recordings of real radar tracks, and alerting performance compared with a state-of-the-art STCA already operational in Lyon TMA. Results indicate that the prototype, parameterised and tuned over a period of weeks, operates within acceptable limits of alerting performance. Recommended improvements include reducing undesirable alert rate between aircraft flying under visual flight rules in uncontrolled class G airspace.
Key deliverables for CM-0807-A – Solution #69 (and for uses of DAPs in other G-SNETs)		
4.8.1-D17	OR-DAP-G-SNET-V2 Preliminary OR for the use of DAP in G-SNETs	This V2 OSED introduces the operational concept for collision avoidance, supported by ground based safety nets: Short term conflict alert (STCA), Minimum safe altitude warning (MSAW), Area proximity warning (APW) and Approach path monitor (APM). Operating methods for each safety net are described considering potential new uses of down-linked aircraft parameters (DAPs) in light of results of recent performance evaluations: Barometric Pressure Setting, MCP/FCU Selected Altitude, Roll Angle and Track Angle Rate. Details of the Step 1 operational environment are given. Operational requirements for each safety net are derived based on existing Eurocontrol specifications published in May 2009. Analysis so far, of the use of DAPs, has not generated any new operational requirements (other than information exchange requirements).
4.8.1-D18	SPR-DAP-G-SNET-V2 Preliminary SPR for G-SNETs using DAP	This V2 SPR focuses on the safety of using existing Mode S down-linked aircraft parameters (DAPs) with the ground based collision avoidance services: short term conflict management, controlled flight into terrain management, and airspace infringement management were assessed. System success and failure approaches are used to derive corresponding performance and safety requirements for the use of DAPs by safety nets within each service (STCA, MSAW, APW and APM). Note that the requirements stay in V2 for MSAW, APW and APM whereas the STCA requirements reached V3 maturity as documented in 4.8.1-D80.
4.8.1-D12	VR-Feasibility-DAP-G-SNET-V2 Feasibility and options for use of DAP in G-SNETs	The purpose of this V2 VALR is to identify the potential uses, limitations, interdependencies and obstructions for each of the existing Mode S Downlinked Aircraft Parameters within new and existing ground-based safety net functions. This document also explores the metrics and scenarios required to assess the feasibility for each potential application in addition to describing the roadmap required for a phased implementation. A preliminary qualitative evaluation of the identified options indicates that the intent based information derived from

		DAPs (such as Selected Altitude) will provide the greatest improvement to ground-based safety nets. Several new ground-based safety nets and monitoring applications based on DAP derived data are identified. Finally, a list of the high priority and medium priority potential uses of DAPs within ground-based safety nets is provided, and whether further assessment is recommended.
4.8.1-D16	VR-Costs-DAP-G-SNET-V2 Estimated costs for the use of DAP in G-SNETs	The purpose of this V2 VALR is to provide guidance to evaluate the resources (and hence costs) required to implement (and if necessary maintain) existing DAPs within ground-based safety nets. The document provides estimates of the following key costs: • implementation of the software changes (to the safety net), in 9 scenarios; • ATC training, in 3 scenarios; • simulations and trials (controller time); • tuning, maintenance and performance monitoring. The document also identifies additional costs, which are not estimated during this study but which should be considered / reviewed prior to any implementation.
4.8.1-D20	VALR-DAP-G-SNET-V3 Operational evaluation of enhanced STCA using DAP	This V3 VALR reports on the validation focused on the promising use of some existing DAPs (SFL and TAR) within STCA, conducted using the ENAV IBP in simulations of Milan ACC airspace. The main results from the comparison between the STCA prototype using DAPs and the STCA baseline are: • a reduction of nuisance alerts of between 17% and 26%; • a maintained alert rate of genuine conflicts; • an increased warning time; • a correct operative functioning even during non-nominal cases. Both SFL and TAR provide improvements in terms of STCA performances, although SFL contribution is more evident than the others particularly in en-route scenario.
4.8.1-D80	OSED-DAP-G-SNET-V3 Final OSED for the use of DAPs in G-SNETs	This V3 OSED / SPR is an update after the V3 validation and addresses only STCA. The requirements related to other safety nets (APW, APM and MSAW) are still at V2 maturity and can be found in 4.8.1-D17. Operational requirements for each safety net were derived on existing Eurocontrol specifications published in May 2009. Analysis of the use of DAPs has not generated any new operational requirements (other than information exchange requirements, of which those for Aircraft ID, Final State Selected Altitude, Roll Angle and Track Angle Rate have been validated). Recommendations for further R&D work on non V3 validated uses of DAPs are provided.

		Appendix A is the V3 update of the SPR and also addresses only STCA. The requirements related to other safety nets are still at V2 maturity and can be found in 4.8.1-D18.
Key deliverables for CM-0807-B		
4.8.1-D25	VALR-TRAJ-G-SNET-V2 Validation report -V2- for G-SNETs adapted to 3-4D TRAJ	This V2 VALR describes the outcomes of the validation conducted on the concept of enhancing G-SNETs using ADS-B, which covered a series of options with a focus on STCA and APW, in the perspective of trajectory-based operations The feasibility and safety / performance benefits have been assessed. Costs associated with the various options for change have also been estimated. Many of the results are not fully conclusive (due to the lack of maturity of future En-route / TMA environments in which STCA will be operated in trajectory-based operations). Most promising options for G-SNET evolution have however been identified.
4.8.1-D29	OSED-TRAJ-G-SNET-V2 Preliminary OR for G-SNETs adapted to 3-4D TRAJ	This V2 OSED describes the operational concept of ground based collision avoidance as a set of services: short term conflict management; controlled flight into terrain management; airspace infringement management and management of other hazards. These services are to be enhanced using additional trajectory / airspace data available through wide information sharing / new surveillance means for more accurate detection and resolution of mid-air collision hazards. No fundamental change in the operational concept of ground-based safety nets within collision avoidance is envisaged for trajectory-based operations. SESAR developments which may have an impact upon ground-based safety nets have been identified. Requirements are based on those of Step 1 with additional requirements for STCA and APW to cope with changes identified in trajectory-based operations.
Key deliverables for CM-0803 – Unnumbered solution		
4.8.2-D03	VR-TCAP Validation report for new possible altitude capture laws	During 1000 ft level-off encounters, TCAS II triggers Resolution Advisories (RAs) which are often perceived as operationally undesired by air traffic controllers and flight crews. ICAO has recommended that a technical solution, which consists in implementing new altitude capture laws taking into account TCAS II thresholds, should be studied. The validation has shown that the proposed new altitude capture law reduces the likelihood to receive an RA during a 1000 ft level-off encounter by at least a factor of 30. There are two side effects: • Addition of RAs in very specific geometries. As they occur rarely and are often cases of loss of separation, this issue can be considered as acceptable. A fix has been found, taking the intruder

		altitude into account but requires TCAS output format modifications. • Addition of multiple TAs, with such small frequency that the issue is considered as minor, all the more than flight crews never complained about multiple TAs.
4.8.2-D04	SPR-TCAP Safety & Performance Requirements for altitude capture laws	This document presents the safety and performance requirements for new altitude capture laws taking into account the TCAS II thresholds. The requirements are divided into 5 areas. The first one is related to TCAS, as the new altitude capture law is triggered with conditions among which the triggering of a TA. The second one is related to the availability of the new altitude capture law, as it shall be available under some circumstances. The third one is related to eligible encounter geometries on which the new altitude capture law has to apply. The fourth one is related to the behaviour of the new altitude capture law. The last one is related to the interface with the crew.
4.8.2-D06	VR-APFD Validation report for automatic responses to ACAS RA	TCAS has demonstrated its effectiveness in reducing the risk of mid-air collision. However, the pilots do not very often respond to the triggered RAs exactly as expected by TCAS II and this negatively affects TCAS II safety benefits and compatibility with ATC operations. This document report on the validation of a solution to this issue: linking TCAS with the Auto-Pilot so that the aircraft would automatically respond to the RAs. The validation has shown that: • with a delay of response to RAs equal to or below 4 s, the automatic responses to RAs bring significant additional safety and operational benefits to TCAS II performance, whatever the assumption in terms of equipage and compliance rate to RAs. • during high altitude encounters it is preferable to perform a manoeuvre even with a vertical rate lower than that expected by TCAS rather than using the existing RA climb inhibition feature.
4.8.2-D07	SPR-APFD Safety & Performance Requirements for automatic responses to ACAS RA	This document presents safety and performance requirements for an automatic response to RAs, as derived from two sources: • the validation report for the validation exercise introduced above; • the Minimal Operation Performance Standards (MOPS) for Automatic Flight Guidance and Control Systems and Equipment.
Key deliverables for CM-0802		
4.8.3-D05	GEN-RADL Performance specifications of ACAS monitoring system for the collection of ACAS RA downlink information	The display of ACAS RA downlinked information to the controller is expected to provide timely and dependable information about the events of RAs occurring on board aircraft. This document provides, from a user's perspective,

		the high level operational requirements for the technical system providing the downlinked information.
4.8.1-D86	VALR-RADL-V3 Final validation report on proposed display and use of ACAS RA downlinked information by the controller	This document describes the validation for the proposed display and use of Airborne Collision Avoidance System (ACAS) Resolution Advisory (RA) downlinked information on the controller working position. Due to the difficulty to reproduce realistically the rare safety events that are RAs, the simulation was run with predefined RA events without interaction by the controllers. This validation approach limited the validity of the results. Nevertheless, the results indicated that a presentation of RA on the Controller Working position could increase the controller situational awareness. Some recommendations are given to improve the HMI solution. A final operational concept was not validated and recommendations on further activities to complete V3 maturity are given.
4.8.1-D87	OSED-RADL-V3 ATC operations including the display of ACAS RA downlinked information to the controller	This updated version of the OSED for the display and use of the ACAS RA downlinked information reflects the results of the V3 validation. The document introduces the two options proposed for the operational procedure and the implication in terms of standardisation. It documents the discussion held at a workshop, whose goal was to help select an operational procedure and resulted in the identification of additional safety hazards and a way forward to assess the best option.
Key deliverables for CM-0808, current ACAS		
4.8.2-D10	VALR-OT Validation report on optimising ACAS RA thresholds	During the time since the existing ACAS thresholds were defined, there have been many improvements in aircraft performance and so it seems reasonable that the current ACAS thresholds could be revised in order to better suit today's airspace. Optimising ACAS RA thresholds offers the opportunity to reduce the number of unnecessary RAs while maintaining at least the same level of safety. The validation of the safety and performance of optimising ACAS RA time and distance thresholds showed that: • no new hazards were identified compared to the current version of ACAS (TCAS II v7.1) • risk ratios were not negatively impacted by the use of "Optimised ACAS RA Thresholds" on pair-wise encounters and significantly decreased on multiple-aircraft encounters • about 2/3rd of "1,000ft separation Nuisance IFR/IFR RAs" were avoided
4.8.2-D23	OSED-Update-IT1	This document describes updated ACAS services for enhanced safety in trajectory based operations. It consolidates the operational, functional and performance requirements for optimised imminent mid-air collision management by flight crew and ACAS RAs thanks to an ACAS operating with "Optimised RA Thresholds".

		The proposed solution was considered a short-term option for the transition phase before SESAR performance based operations, which are likely to require the development of a more innovative solution as envisaged by the ICAO's Aviation System Block Upgrade (ASBU) Module B2-101: "New collision avoidance system".
Key deliverables for CM-0808, new ACAS		
4.8.2-D36	OSED-ACASX-CURRENT Operational and performance requirements for ACAS Xa in Europe	This document is the description of updated ACAS services for enhanced safety in SESAR trajectory based operations. This OSED is the result of validation activities on ACAS Xa, the new collision avoidance system under development in the US in the context of the ICAO's Aviation System Block Upgrade (ASBU) Module B2-101: "New collision avoidance system". This document contains very preliminary requirements for ACAS Xa in Europe. No major change in the operational concept of airborne safety nets is envisaged, but rather a new development utilising new technology for the implementation of Airborne Collision Avoidance System.
4.8.1-D92	VALR-ACASX-OPT1 Validation report for the evaluation of ACAS Xa optimized for Europe	This document reports on the fast-time validation of ACAS Xa, the next generation of airborne collision avoidance system for civil aircraft envisaged as an alternative to current TCAS II system. ACAS Xa is still under development through different versions called "Runs". The idea is that the validation of a given Run inputs the design of the following until all operational, safety and performance requirements are met. The conclusion of the document, based on ACAS Xa Runs 13 and 14, is that: • the development is converging towards a promising system with the latest Run providing safety benefits (e.g. 35% reduction in Risk Ratio). • ACAS Xa Run 14 only partially achieves the expectations and areas of improvement still exist.
4.8.1-D95	VALR-ACASX-HP Validation report for the assessment of human performance aspects of ACAS Xa	This document reports on the human-in-the-loop validation of ACAS Xa, the next generation of airborne collision avoidance system for civil aircraft envisaged as an alternative to current TCAS II system. An industrial prototype of ACAS Xa Run 14 was integrated in a cockpit simulator. Pilots from various companies were presented with 12 situations spread over a flight from LFPG to EGLL and back. Their feedback was collected through in-flight questionnaires and after-flight questionnaire and debriefing.
4.8.1-D90	SPR-ACASX-OPT1 Requirements of an optimized ACAS Xa logic for current European operations	This document is an update of the SPR related to ACAS Xa. The safety requirements are derived mainly from the Initial Safety Assessment previously conducted and from the OSED. A pilot workshop has also been undertaken to understand the operational acceptability of Resolution Advisories generated by ACAS and to refine the safety

		requirements as well as provide performance recommendations. The project acknowledges that the requirements listed within this SPR may be treated as recommendations by the FAA ACAS Xa Project team.
4.8.1-D101	GEN-ACASX-Acceptability SESAR vision of European acceptability criteria for ACAS Xa development	This document provides a set of measurable metrics and associated thresholds by which European acceptance of ACAS Xa can be objectively decided. It can be used both by validation teams to identify areas of improvement and by regulatory authorities to support a decision related to the introduction of ACAS Xa in Europe. The list is intended to permit to measure ACAS Xa ability to maintain an appropriate level of benefits while limiting potential drawbacks to European operations. It relies on the experience gained from SESAR validation activities performed on ACAS Xa since Run 9 and from historical background on TCAS II operations.
Key transversal deliverable		
4.8.1-D99	GEN-Input-CONOPS Input for Global Concept of Operation for Collision Avoidance	This technical note describes the European input for a global concept of operation for collision avoidance. Such a concept exists in too general terms in the ICAO Global ATM Operational Concept (Doc 9854). This document provides an overview of conflict management, identifies positive as well as negative interactions between system elements (people, procedures and technical systems) within the collision avoidance layer itself and within conflict management as a whole, and identifies ways to influence these interactions.

1.4 Contribution to Standardisation

No standards exist for ground-based safety nets.

In the context of the unnumbered solution, the project was highly involved in the drafting group of EUROCAE WG-75 that led to the publication of ED-224, *MASPS for Flight Guidance System (FGS) Coupled to Traffic Alert and Collision Avoidance System (TCAS)*. These MASPS were heavily based on the project SPRs addressing the automatic response to RAs and the reduction of vertical speed when approaching the CFL.

Since the reorientation of ACAS activities to support the development of the new ACAS, called ACAS Xa, the project has been contributing to the drafting of a new MOPS, based on current TCAS MOPS (RTCA DO-185B / EUROCAE ED-143), in two ways:

- dissemination of validation results identifying areas of improvement for a better performance of ACAS Xa in Europe
- involvement in the working group in charge of drafting the new MOPS

The development of these MOPS is a joint RTCA SC-147 and EUROCAE WG-75 activity and is planned to conclude in mid-2018.

1.5 Project Conclusion and Recommendations

The project successfully worked towards its aims of improving safety nets performance and adapting them to future operations. From an ATM Master Plan perspective, this success is shown by the completion of three OI steps and significant progress of two OI steps.

From a programme perspective, this success is materialised by:

- the production of two solutions related to STCA and one related to ACAS, allowing significant improvements to safety and operational acceptability;
- the highlighting of potential improvements of G-SNETs performance using availability of new or more accurate trajectory and airspace data (from EHS, ADS-B and SWIM);
- good progress on the way to avoid possible contradictions between STCA-triggered controller instructions and ACAS-triggered pilot manoeuvres;
- a significant contribution to the development of the new ACAS system, with a focus on bringing benefits for the European airspace.

To get the full benefits of the project successes, it is recommended (in no priority order) that:

- the availability of the three mature solutions be advertised to the appropriate stakeholders for consideration of implementation;
- due to its network-wide nature, the solution that improves ACAS operations be taken onboard by the deployment manager and incentives for airlines to equip be established;
- future R&D activities build on the project results on the uses of Mode S DAPs and ADS-B / SWIM data to progress further the evolution of G-SNETs adapted to trajectory-based operations. Work to be progressed include to refine the expected benefits from the most promising options identified by the project and to fully develop the concepts (and associated systems and interfaces) for which the benefits and feasibility are confirmed;
- future R&D activities complete the validation of ACAS Xa to ensure that the final development stage takes into account European safety and performance requirements anticipated for trajectory-based operations, and addresses properly the essential human factor issue of pilot acceptability. Input to RTCA/EUROCAE meetings will be needed in order to produce the associated MOPS.
- future R&D activities complete the development and the safety assessment of the operational concept for the use by the controller of RA information displayed on the CWP.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] SESAR P04.08.01, SPR-STCA-V2 Consolidated baseline framework for safety and performance, D03, 00.01.00

[5] SESAR P04.08.01, VP-TMA-STCA-V3 Final validation plan (V3) for enhanced STCA for TMA specific operations, D04, 00.01.00

[6] SESAR P04.08.01, VR-TMA-STCA-V3 Operational evaluation of industrial STCA prototype for TMA, D05, 01.00.00

[7] SESAR P04.08.01, DP-G-SNET-STEP1 Initial development plan for G-SNETs evolution using DAPs, D06, 00.01.00

[8] SESAR P04.08.01, DP-DAP-G-SNET-V2 Initial development plan for the use of existing down-link parameters in ground-based safety nets, D10, 00.01.00

[9] SESAR P04.08.01, VP-DAP-G-SNET-V2 Validation Plan (V2) for G-SNETs using DAP, D11, 00.01.00

[10] SESAR P04.08.01, VR-Feasibility-DAP-G-SNET-V2 Feasibility and options for use of DAP in G-SNETs, D12, 00.01.01

[11] SESAR P04.08.01, VR-Benefits-DAP-STCA-V2 Model-based performance evaluation of STCA using DAP, D13, 00.01.01

[12] SESAR P04.08.01, VR-Benefits-DAP-Other-G-SNET-V2 Evaluation of safety benefits of other G-SNETs using DAP, D14, 00.01.01

[13] SESAR P04.08.01, SAR-Safety-DAP-G-SNET-V2 Safety assurance elements for the use of existing down-linked aircraft parameters in ground-based safety nets, D15, 00.01.00

[14] SESAR P04.08.01, VR-Costs-DAP-G-SNET-V2 Estimated costs for the use of DAP in G-SNETs, D16, 00.01.00

[15] SESAR P04.08.01, OR-DAP-G-SNET-V2 Preliminary OR for the use of DAP in G-SNETs, D17, 01.01.00

[16] SESAR P04.08.01, SPR-DAP-G-SNET-V2 Preliminary SPR for G-SNETs using DAP, D18, 00.01.00

[17] SESAR P04.08.01, VALP-DAP-G-SNET-V3 Validation Plan -V3- for enhanced STCA using DAP, D19, 00.01.00

[18] SESAR P04.08.01, VALR-DAP-G-SNET-V3 Operational evaluation of enhanced STCA using DAP, D20, 00.01.01

[19] SESAR P04.08.01, DP-34D-G-SNET-V1 Initial development plan for G-SNETs evolution for future 3/4D trajectory operations with ground-based separation, D21, 00.01.01

[20] SESAR P04.08.01, OSED-TRAJ-G-SNET-V1 Initial operational concept for G-SNETs adapted to 3-4D TRAJ, D22, 00.01.00

[21] SESAR P04.08.01, VALP-TRAJ-G-SNET-V2 Validation plan (V2) for G-SNETs adapted to 3-4D TRAJ, D24, 00.01.00

[22] SESAR P04.08.01, VALR-TRAJ-G-SNET-V2 Validation report (V2) for G-SNETs adapted to 3-4D TRAJ, D25, 00.01.00

[23] SESAR P04.08.01, OSED-TRAJ-G-SNET-V2 Preliminary OR for G-SNETs adapted to 3-4D TRAJ, D29, 00.01.00

[24] SESAR P04.08.01, OSED-DAP-G-SNET-V3 Final OSED for the use of DAPs in G-SNETs, D80, 00.01.03

[25] SESAR P04.08.01, VALP-RADL-V2 Preliminary validation plan of proposed display and use of ACAS RA downlinked information by the controller, D82, 00.01.00

[26] SESAR P04.08.01, VALR-RADL-V2 Preliminary validation report on proposed display and use of ACAS RA downlinked information by the controller, D83, 00.01.00

[27] SESAR P04.08.01, OSED-RADL-V2 ATC operations including the display of ACAS RA downlinked information to the controller, D84, 00.01.01

[28] SESAR P04.08.01, VALP-RADL-V3 Final validation plan of proposed display and use of ACAS RA downlinked information by the controller, D85, 00.01.00

[29] SESAR P04.08.01, VALR-RADL-V3 Final validation report on proposed display and use of ACAS RA downlinked information by the controller, D86, 00.01.02

[30] SESAR P04.08.01, OSED-RADL-V3 ATC operations including the display of ACAS RA downlinked information to the controller, D87, 00.01.03

[31] SESAR P04.08.01, SPR-ACASX-CURRENT Safety assessment of ACAS Xa in Europe, D88, 00.01.02

[32] SESAR P04.08.01, VALR-ACASX-CURRENT Validation report for the evaluation of ACAS Xa in Europe, D89, 00.01.01

[33] SESAR P04.08.01, SPR-ACASX-OPT1 Requirements of an optimized ACAS Xa logic for current European operations, D90, 00.01.02

[34] SESAR P04.08.01, VALP-ACASX-OPT1 Validation plan for the evaluation of ACAS Xa optimized for Europe, D91, 00.01.00

[35] SESAR P04.08.01, VALR-ACASX-OPT1 Validation report for the evaluation of ACAS Xa optimized for Europe, D92, 00.01.01

[36] SESAR P04.08.01, VALP-ACASX-HP Validation plan for the assessment of performance aspects of ACAS Xa, D94, 00.01.01

[37] SESAR P04.08.01, VALR-ACASX-HP Validation report for the assessment of human performance aspects of ACAS Xa, D95, 00.01.00, 20/06/2016

[38] SESAR P04.08.01, GEN-Roadmap-EM Initial Step 2 Technical Note: Roadmap for European (or Global) Encounter Models, D97, 00.01.02

[39] SESAR P04.08.01, GEN-ACASX-Acceptability SESAR vision of European acceptability criteria for ACAS Xa development, 101, 00.01.02

[40] SESAR P04.08.01, GEN-Roadmap-EM2 Updated roadmap for European encounter models and validation platform, D98, 00.01.10

[41] SESAR P04.08.01, GEN-Input-CONOPS Input for Global Concept of Operation for Collision Avoidance, D99, 00.01.01

[42] SESAR P04.08.02, VP-TCAP Validation plan for new possible altitude capture laws, D02, 00.01.00

[43] SESAR P04.08.02, VR-TCAP Validation report for new possible altitude capture laws, D03, 00.01.01

[44] SESAR P04.08.02, SPR-TCAP Safety and Performance Requirements for new possible altitude capture laws, D04, 00.01.00

[45] SESAR P04.08.02, VP-APFD Validation plan for automatic responses to ACAS RA, D05, 00.01.00

[46] SESAR P04.08.02, VR-APFD Validation report for automatic responses to ACAS RA, D06, 00.01.01

[47] SESAR P04.08.02, SPR-APFD SPR for automatic responses to ACAS RAs, D07, 00.01.01

[48] SESAR P04.08.02, OSED-INITIAL-ACAS ACAS modifications for time & trajectory based operations initial OSED, D08, 00.01.00

[49] SESAR P04.08.02, VP-CURRENT Validation plan of possible ACAS modifications for time & trajectory-based operations, D09, 00.01.00

[50] SESAR P04.08.02, VALR-OT Validation Report on Optimising ACAS RA Thresholds, D10, 00.01.01

[51] SESAR P04.08.02, VR-NONACAS Validation report on potentially improving compatibility of non-ACAS aircraft with ACAS, D11, 00.01.00

[52] SESAR P04.08.02, VR-TRAJ Feasibility report of using trajectory data in ACAS, D12, 00.01.01

[53] SESAR P04.08.02, OSED-IT1, ACAS modifications for trajectory based operations - Updated OSED (Iteration 1), D23, 00.01.00

[54] SESAR P04.08.02, OSED-ACASX-CURRENT Operational and Performance requirements for ACAS Xa in Europe, D36, 00.01.01

[55] SESAR P04.08.03, PR-RADL Performance Specifications of ACAS Monitoring System for the collection of ACAS RA downlink information, D05, 00.01.00

[56] SESAR P04.08.03, OCD-RADL ATC operations including the display of ACAS RA downlinked information to the controller - initial version, D07, 00.01.00

Appendix A Status of the remaining issue on incomplete validation of ACAS Xa in the European airspace

As explained in issue 5290, there is an incomplete validation of ACAS Xa in the European airspace, with the possible consequence that ACAS Xa will not be performing satisfactorily in Europe due to undetected safety and operational issues.

ACAS Xa is developed through versions called Runs. Nearly all desirable validation activities were conducted on Runs 11 and 12. However, given the way a new Run is produced, it is impossible to guarantee that the resolution of an issue identified in a previous Run will not degrade the system performance in an area that was addressed satisfactorily before. As the issue points out, this is not done for the European validation of the versions 13 and 14, which are within the scope of SESAR 1.

The table below indicates all the validation scenarios that should be looked at in order to uncover nearly (as it is not possible to guarantee 100% coverage) all possible issues for Europe, but shows what was not done for Runs 13 and 14 as stricken out text.

	Sources of encounters				
Equipage Scenarios	**European safety encounter model (AVAL)**	**~~European day-to-day encounter model (PASS)~~**	**~~Vertical chase encounter model (SA01)~~**	**~~Multi-aircraft safety encounter model (multi ASARP)~~**	**Radar encounters**
Full TCAS II (v7.1~~ & v7.1 with OT~~)	Standard Typical ~~AP/FD~~	~~Standard~~ ~~Typical~~ ~~TCAP & AP/FD~~	~~Standard & non-response~~ ~~Typical & non-response~~	~~Standard~~	Standard
Full ACAS Xa	Standard Typical ~~AP/FD~~	~~Standard~~ ~~Typical~~ ~~TCAP & AP/FD~~	~~Standard & non-response~~ ~~Typical & non-response~~	~~Standard~~	Standard
Partial ACAS Xa	Standard	~~Standard~~	~~Standard & non-response~~	~~/~~	/

As a consequence, it was not possible to compute all the metrics recommended in [39] to check acceptability of these versions of ACAS Xa in Europe.

Possible issues in the not-covered areas (operational suitability of ACAS Xa in Europe, SA01 situations and multi-aircraft encounters, effect on operational improvements using a link between ACAS and autoflight systems that were previously validated in SESAR) are therefore undetected and couldn't be pointed out to FAA for possible correction in the last Run, Run 15. So, the risk that Run 15 will not end up with the best compromise for Europe is high.

If EUROCAE decides to stamp RTCA standards and ACAS Xa is authorized to fly in Europe without a complete European validation, flight safety and operational acceptability of ACAS may decrease due to undetected issues.

As the validation experts will have been inactive on ACAS Xa for a long time, there will be a loss of European expertise in ACAS. If an ACAS Xa implementation issue arises in Europe, it will be more difficult and more costly to address it, both because of the loss of expertise and because of the late detection of the issue (after the standardization).

On the other hand, if ACAS Xa is not authorized to fly in Europe without a complete European validation, performance improvements expected from ACAS Xa will be not be delivered on time. Also, in this case, companies equipped with ACAS Xa and operating transatlantic flights will have to also remain equipped with TCAS v7.1 which will be an additional cost.

As of the delivery of this Final Project Report, the only remaining mitigation is that all the desirable validation activities are conducted for Run 15, otherwise issues may go undetected until ACAS Xa has been deployed in Europe. Hopefully, FAA will be able to minimize the newly identified issues, although in a lesser extent than if they had been detected in Run 14, and maybe not to a level where ACAS Xa is acceptable for Europe.

-END OF DOCUMENT-