SESAR Solution PJ.11-A1: Cost Benefit Analysis report for V3

Deliverable ID:	**D3.1.050**
Dissemination Level:	**PU**
Project Acronym:	**CAPITO**
Grant:	**732996**
Call:	**H2020-SESAR-2015-2**
Topic:	**Enhanced Air and Ground Safety Nets**
Consortium coordinator:	**EUROCONTROL**
Edition date:	**28 October 2019**
Edition:	**00.01.01**
Template Edition:	**02.00.01**

Founding Members

EUROPEAN UNION EUROCONTROL

SESAR JOINT UNDERTAKING

Founding Members

EUROPEAN UNION EUROCONTROL

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Désirée Teunissen / EUROCONTROL	CBA Analyst	July 2019

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Massimiliano Amirfeiz / Leonardo	PJ11 Project Member	13 September 2019
Christian Aveneau / DSNA	PJ11-A1 Solution Leader	13 September 2019
Bill Booth / EUROCONTROL	PJ11 Project Leader	13 September 2019
Jamal Chehade / EUROCONTROL	PJ11 Project Member	13 September 2019
Stan Drozdowski / EUROCONTROL	PJ11 Project Member	13 September 2019
Marco Gibellini /EUROCONTROL	PJ19-4-3 Lead	13 September 2019
Volker Huck / EUROCONTROL	PJ11 Project Member	13 September 2019
Bryan Hickling / EUROCONTROL	PJ11 Project Member	13 September 2019
Paula Leal de Matos / EUROCONTROL	PJ11 Project Member	13 September 2019

Approved for submission to the SJU By – Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Andre Marques / Airbus	PJ.11-A1 solution member	13 September 2019
Marie-Gabrielle Lafoucrière / Dassault	PJ11-A1 solution member	13 September 2019
Christian Aveneau / DSNA	PJ11-A1 solution leader	13 September 2019
Bill Booth / Eurocontrol	PJ.11 Coordinator	13 September 2019
Tereza K. Spalenkova /Honeywell	Contribution Manager	13 September 2019

Rejected By – Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification

00.00.02	July 2019	Draft	Desiree Teunissen	First draft building on V2 Interim CBA
00.00.03	September 2019	Final Draft	Desiree Teunissen	Final Draft
00.01.00	30 September 2019	Final	Desiree Teunissen	Submitted to Solution Leader
00.01.01	28 October 2019	Final	Desiree Teunissen	SJU review

Copyright Statement

CAPITO

COLLISION AVOIDANCE PERFORMANCE IMPROVEMENT TECHNOLOGY

This Cost Benefit Analysis 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 provides the V3 Cost Benefit Analysis (CBA) for SESAR Project PJ.11 solution A1-(in WP3).

Solution PJ11-A1 concentrates on improvements to the current Airborne Collision Avoidance System for Commercial Air Traffic – ACAS Xa by taking advantage of optimised resolution advisories and of additional surveillance data, without changing the cockpit interface.

This V3 CBA estimates costs and provides evidence on the benefits of a potential deployment of the Solution PJ11-A1 across ECAC.

Table of Contents

List of Tables

List of Figures

1 Executive Summary

This document[1] provides the V3 Cost Benefit Analysis (CBA) of SESAR Solution PJ11-A1, ACAS Xa, a solution already validated to V2 maturity phase in SESAR 1.

PJ11-A1 concentrates on improvements to the current Airborne Collision Avoidance System for Commercial Air Traffic, incorporated in the ACAS Xa solution which takes advantage of optimised resolution advisories and of additional surveillance data, without changing the cockpit interface.

The path to this solution started in SESAR 1. It supports the development of a replacement to TCAS II (in collaboration with the FAA) that will resolve more Near Mid-Air Collisions (NMAC) and produce fewer unnecessary alerts. PJ11-A1 continues SESAR 1 work and aims to reach V3 maturity for the solution.

The main expected benefit of this solution is an **increase in safety** by reducing the proportion of NMACs. In addition, there could be other benefits such as, an **increase in ANS Cost efficiency** (by reducing the ATCO workload, the number of investigation resulting from NMAC and the number of go-arounds), an **increase in capacity** (less disruption of traffic) and **improvements in Human Performance** (increased Pilots'confidence in ATM systems alerts). There are no negative impacts expected on Military operations.

The deployment of PJ11-A1 will require the following stakeholders to invest:

- **Civil and Military ANSPs** in charge of the investigations and analysis of operations
- The **Airspace users** who will benefit from optimised resolution advisories

The safety benefits of the solution are assessed in terms of proportion of NMACs avoided. Results from validation show a general reduction of 16% in NMAC, on one model, when all the fleet is equipped. When looking at specific layers in the airspace, however, there is no benefit in en-route. During the transition period, when an ACAS Xa equipped aircraft meets a TCAS II equipped aircraft there can be even more NMACs in some layers. These issues for particular configurations are being investigated, but may slow the acceptance of the system by EASA (European Aviation Safety Agency).

The costs include the ANSP investments to deploy the Solution at Area Control Centres. The ANSP investment data is based on the estimates to upgrade the software. The investment costs for the Airspace Users are the cost of equipping the fleet with the tool ACAS Xa. The equipage costs have been estimated based on past estimates of TCAS II costs in the US and Europe [13][15]. Considering the uncertainty on these estimates, a range of Low-High values has been used.

[1] "The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein."

The CBA compares the Scenario without the Solution, the Reference Scenario, against two Solution Scenarios: 1) solution deployment assuming forward fit only and 2) solution deployment assuming a mandate in 2030 with 16 months implementation.

The Present Value (PV) of the cost for each scenario is given below. The calculation uses an 8% discount rate [5] and is calculated between 2019 and 2040 with Solution deployment starting in 2025. There is no calculation of benefits or payback year, as the benefits are not monetised.

1. **Scenario 1: Deployment with no mandate, forward fit only**

   The **cost PV** (2019-2040) ranges between **225 and 392 M€**

   In this scenario, by 2040 only 70% of the fleet would be equipped

2. **Scenario 2: deployment with mandate in 2030 with 16 months implementation**

   The **cost PV** (2019-2040) ranges between **883 and 1 382 M€**

The wide cost interval estimated for the equipage cost indicates that the cost for deploying this solution in ECAC could easily reach values above 1 B€, especially in a scenario with mandate. A total cost of this magnitude needs to be balanced by clear and robust evidence on the Safety Benefits that this solution can bring to ECAC. This evidence should be provided by the next validation exercise of the solution planned for the end of 2019.

2 Introduction

2.1 Purpose of the document

This document provides the V3 Cost Benefit Analysis (CBA) based on an ECAC-level view of the deployment of **SESAR Solution PJ.11-A1: Airborne Collision Avoidance System for Commercial Air Traffic - ACAS Xa.** It allows the SJU to evaluate the affordability of this Solution with respect to its benefits.

2.2 Scope

Solution PJ11-A1 covers the following OI Step:

CM-0808-a: (EATMA Data Set 19) Airborne Collision Avoidance for commercial air transport in standard operations, taking advantage of surveillance data from passive sources (ADS-B), additional aircraft data, providing optimized resolution advisories and improving compatibility with non-equipped aircraft.

The geographical scope of this CBA is the ECAC area and the main stakeholders are ANSPs (civil and military) and Airspace Users.

2.3 Intended readership

The intended audience of this document is:

- PJ.11 Members
- PJ.19 as the Content Integration Project
- SESAR Programme Management
- PJ.20 Master Plan Maintenance project

2.4 Structure of the document

The following sections for this document cover:

- Section 1 provides the executive summary
- Section 2 provides an introduction to the document
- Section 3 describes the objectives and scope of the V3 CBA including an overview of the concept and details of the CBA Scenarios
- Sections 4 and 5 detail, respectively, the benefits and the costs
- Sections 6, 7, 8 and 9 contain, respectively, details of the CBA model, data sources, the CBA results and the sensitivity analysis
- Section 9 focuses on sensitivity and risk
- Section 10 makes recommendations and identifies next steps
- Section 11 provides the references and applicable documents

2.5 Background

The International Civil Aviation Organization (ICAO) defines **"Conflict Management"** as the process used for limiting, to an acceptable level, the risk of collision between aircraft and hazards ([11]). In the context of separation, ICAO defines hazards as "objects or elements that an aircraft can be separated from". These are: other aircraft, terrain, weather, wake turbulence, incompatible airspace activity and, when the aircraft is on the ground, surface vehicles and other obstructions on the apron and manoeuvring area. "**Collision avoidance**" is the third and last layer of conflict management that specifically addresses short-term conflicts. Its role is, according to ICAO [11] "the additional and independent level of conflict management to that provided by separation provision". ACAS (Airborne Collision Avoidance System) is one of the collision avoidance systems.

ICAO defines **ACAS** as [12]: "An aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to detect and process proximate traffic, and then provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders". ACAS is the last resort safety net for pilots. Although ACAS is independent from the means of separation provision, they must be compatible; therefore, ACAS is part of the ATM system.

Solution **PJ11-A1** concentrates on improvements to the current Airborne Collision Avoidance System for Commercial Air Traffic incorporated in the ACAS Xa solution by taking advantage of optimised resolution advisories and of additional surveillance data, without significantly changing the cockpit interface.

The path to this solution was already started in SESAR 1 [16][17]. It supports the development of a replacement to TCAS II (in collaboration with the FAA [9]) that will resolve more NMACs and produce fewer nuisance alerts. PJ11-A1 continues this SESAR 1 work and aims to reach V3 maturity for the solution.

Furthermore, it is worthwhile to mention that the FAA and ECAC relevant authorities are coordinating the certification and introduction of ACAS Xa. Currently for live trial purposes FAA have 20 aircraft flying with the solution on commercial aircraft on normal operations.

2.6 Glossary of terms

Term	Definition	Source of the definition
Cost Benefit Analysis	A Cost Benefit Analysis is a process of quantifying in economic terms the costs and benefits of a project or a program over a certain period, and those of its alternatives (within the same period), in order to have a single scale of comparison for unbiased evaluation.	*SESAR 1* *(Section 10.2 [6])*
Business Case	A Business Case is a neutral financial tool that helps decision makers to compare an investment with other possible investments and/or to make a choice between different options / scenarios and to select the one that offers the best	*SESAR 1* *(Section 10.2 [6])*

	value for money while considering all the key criteria for the decision. A Business Case has a wider scope than a CBA.	
Enabler	An Enabler represents new or modified technical system/infrastructure, human factors element, procedure, standard or regulation necessary to make (or enhance) an operational improvement.	*SESAR European ATM Architecture (EATMA) Framework*
Full Operational Capability (FOC)	FOC is reached when the maximum effective number of "instantiations" or deployments of an OI Step (or enabler) have reached Operating Capability. *For the CBA this reflects the time when full benefits will be realised and when investment costs are considered to end*.	*SESAR ATM Lexicon https://ext.eurocontrol.int/lexicon/index.php/SESAR* *extended by the Solution Project*
Go-around	A go-around occurs when an aircrew makes the decision not to continue an approach, or not to continue a landing, and follows procedures to conduct another approach or to divert to another airport.	*SKYBRARY* *https://www.skybrary.aero/index.php/Go_Around*
Initial Operating Capability (IOC)	Indicates the date from which benefits can be expected. *For the CBA this reflects the start of the benefit ramp up period and the start of any operating cost impacts.*	*SESAR ATM Lexicon https://ext.eurocontrol.int/lexicon/index.php/SESAR99* *extended by the Solution Project*
Near Mid-air Collision (NMAC)	Two aircraft simultaneously coming within 100 feet vertically and 500 feet (0.08 NM) horizontally.	*EUROCONTROL ACAS Guide (December 2017)* https://www.eurocontrol.int/sites/default/files/2019-03/safety-acas-2-guide.pdf
Present Value	Present value (PV) is the current value of a future sum of money or stream of cash flow given a specified rate of return	*Investopedia*
Terminal manoeuvring area	Designated area of controlled airspace surrounding a major airport where there is a high volume of traffic	*EUROCONTROL Performance Review Unit*

2.7 List of Acronyms

Acronym	Definition
ACAS	Airborne Collision Avoidance System
ACAS Xa	Airborne Collision Avoidance System for Commercial Air Traffic
ACAS Xu	Airborne Collision Avoidance System for Remotely Piloted Aircraft Systems
A/C	Aircraft
ACC	Area Control Centre
ACE	ATM Cost-Effectiveness
ADS-B	Automatic dependent surveillance-broadcast
AFGS	Automatic Flight Guidance System
ANSP	Air Navigation Service Provider
ATCO	Air Traffic Controller
ATM	Air Traffic Management
AU	Airspace Users
BA	Business Aviation
BIM	Benefit Impact Mechanism
CAP	Capacity
CBA	Cost Benefit Analysis
CEF	Cost Efficiency
CONOPS	Concept of Operations
DSNA	Direction des Services de la navigation aérienne (France)
EASA	European Aviation Safety Agency
EUROCONTROL	European Organisation for the Safety of Air Navigation
EATMA	(SESAR) European ATM Architecture
ECAC	European Civil Aviation Conference
EXE05	Validation exercise # 05
EUROCAE	European Organisation for Civil Aviation Equipment
FAA	Federal Aviation Agency (USA)
FOC	Final Operational Capability
GAT	General Air Traffic
HC	High complexity (airport)
HP	Human Performance

IFR	Instrument flight rules
LC	Low complexity (airport)
IOC	Initial Operational Capability
KPA	Key Performance Area
KPI	Key Performance Indicators
MASPS	Minimum Aircraft System Performance Specification
MP	Masterplan
MOPS	Minimum Operational Performance Standards
MTOM	Maximum Take-off Mass
NM	Network Manager
NMAC	Near Mid Air Collision
OE	Operating Environment
OI	Operational Improvement
PAR	Performance Assessment Report
PIRM	Programme Information Reference Model
PJ	Project
PMP	Project Management Plan
PRISME	Pan-European Repository of Information Supporting the Management of European ATM
PV	Present Value
Q4	Fourth quarter of a calendar year
RA	Resolution Advisory
RTCA	Radio Technical Commission for Aeronautics
SA	Scheduled Airlines
SAF	Safety
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SSR	Secondary Surveillance Radar
STATFOR	Statistics and Forecast (EUROCONTROL)
TCAS	Traffic collision Avoidance System
TMA	Terminal manoeuvring area
VALR	Validation Report

V3	Pre-industrial development and integration stage of the Concept Lifecycle Model (E-OCVM)

3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

This solution is deployed to prevent the occurrence of Mid-Air and Near Mid-Air Collisions (NMACs). It should solve more Mid-Air and Near Mid-Air Collisions than current TCAS II (Currently TCAS is mandated on board of all civil a/c above 5.7 tons MTOM and/or capable to carry more than 19 passengers)[2].

Current TCAS II has a number of unnecessary alerts, unnecessary Go-arounds at low altitude and additional costs of RA investigations.

3.2 SESAR Solution description

Solution PJ11-A1 concentrates in improving on current Airborne Collision Avoidance for Commercial Air Traffic by taking advantage of optimized resolution advisories and of additional surveillance data, without changing the cockpit interface (same alerts and presentation). The concept under validation for Europe is ACAS Xa, developed by FAA [9], which is the member of the ACAS X family expected to replace TCAS II.

It supports development of replacement to TCAS II (in collaboration with the FAA) that will resolve more Near Mid-Air Collisions and produce fewer unnecessary alerts.

The objectives of solution PJ11-A1 are to:

- ensure that the new concept will deliver safety and operational benefits in Europe and not only in the USA. The idea is that ACAS Xa net safety benefit should be at least as good as TCAS II to be acceptable in European airspace and preferably better;
- check that flight crew confidence in the collision avoidance system (and thus the good manual response to the alerts) is maintained;
- analyse the interaction of ACAS Xa with a specific European aircraft feature developed in SESAR 1, reduction of vertical speed when approaching a cleared flight level, and possibly propose adaptation of this feature if an issue is identified;
- consider the possible introduction of ACAS Xa in Europe.

[2] In this document, TCAS II refers to TCAS II version 7.1 (EUROCAE ED-143/RTCA DO-185B), unless otherwise noted.

SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from the Integrated Roadmap)	OI step coverage	Comments on the OI step title / definition
PJ11-A1	CM-0808-a	Improved Collision Avoidance for Commercial Air transport in standard operations (ACAS Xa)	All ECAC States	Airborne Collision Avoidance for commercial air transport in standard operations, taking advantage of surveillance data from passive sources (ADS-B), additional aircraft data, providing optimized resolution advisories and improving compatibility with non-equipped aircraft.

Table 1: SESAR Solution PJ.11-A1 Scope and related OI steps
(Source: EATMA Dataset 19)

OI Steps ref.	Enabler[3] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Comments on the Enabler / definition
CM-0808-a	A/C 54a	Enhanced ACAS	All ECAC States	AU and ANSPs	Enhanced ACAS with **reduced threshold,** use of ADS-B horizontal information, extended hybrid surveillance for non ACAS aircraft with ACAS aircraft improved **compatibility with US ACAS Xa**

Table 2: OI steps and related Enablers
(Source: EATMA Dataset 19)

Regarding the enablers, the following modifications have been proposed by solution PJ11-A1:

[3] This includes System, Procedural, Human, Standardisation and Regulation Enablers

- A/C-54a - Enhanced Airborne Collision Avoidance (ACAS) - scope is too wide, therefore assessing its maturity would not reflect the actual maturity of the system enabling CM-0808-a;
- STD-074 - MASPS for AFGS / ACAS-coupling - is not an enabler of CM-0808-a, as the solution described in this standard is an addition to any ACAS, designed to enhance ACAS operations, whether with current or future systems
- STD-075 - ACAS-Xu MOPS - is not an enabler of CM-0808-a as this standard covers collision avoidance for RPAS (solution PJ11-A2, and solution PJ.11-A4 which is expected to use ACAS Xu as a baseline).

A Change Request is ongoing to address them and the consequences for other PJ11 ACAS X related solutions.

3.3 Objectives of the CBA

This V3 CBA is required to assess the affordability and economic feasibility of the solution with respect to its expected benefits.

The CBA provides the estimated costs and benefits of deploying the Solution in an ECAC-level CBA Scenario to help build the 'big picture'. While the views of individual stakeholders involved in the deployment are considered, this CBA task does not provide CBA results for specific local deployments.

PJ11-A1 is a safety net solution therefore the main benefit, in terms of avoidance of Mid-Air Collisions, is not monetised. However, evidence from validation demonstrating these Safety benefits is provided.

3.4 Stakeholders[4] identification

This section includes the stakeholders and impacts captured in the CBA.

Stakeholder	The type of stakeholder and/or applicable sub-OE	Type of Impact	Involvement in the analysis	Quantitative results available in the current CBA version
ANSP	TMA, En route	**Benefit:** - Safety benefit: ACAS Xa will solve more Near Mid-Air Collisions than current TCAS II - Cost efficiency: reduction of investigation due to fewer NMACs	DSNA EUROCONTROL	Ongoing validation of Safety benefit. To be concluded in Q4 2019

[4] Note that the terminology used to describe AU stakeholders in the CBA differs from that associated with Enablers in the dataset. This is due to costing being provided for different types of aircraft regardless of the operations they perform.

		- ATCO productivity: Reduction of ACAS unnecessary alarms and so reduction of the possibility of knock-on conflicts due to unnecessary RA induced manoeuvres **Costs** - Investment in upgrading investigation software (that reproduces what occurred), and cost of training the investigators (<>1 week) only for bigger ANSPs - Upgrade of software to collect ACAS RA on the ground which requires a change of format		For other benefits there is limited data for quantifica-tion (see Section 4 for more details) Costs of ANSPs can be found in Section 5.1
Military	TMA, En route	Same impact as for civil AU GAT traffic Investments similar to civil airspace users	EUROCONTROL	N/A
Civil Airspace Users		**Benefit:** - Safety benefit: ACAS Xa will solve more NMACs than current TCAS II without changing the cockpit interface - Reduction in TCAS II unnecessary alarms and the cost of resulting RA (e.g. changes in altitude, additional distance and fuel burn) - Cost efficiency: reduction in number of go around - HP benefit: Increased flight crew trust in advisories **Costs** - Investment in ACAS Xa hardware and software - Change in flight crew documentation	N/A	Ongoing validation of Safety benefit to be concluded in Q4 2019 For other benefits there is insufficient data for quantification Costs of Civil Airspace Users can be found in Section 5.4

Table 3: SESAR Solution PJ.11-A1 CBA Stakeholders and impacts

3.5 CBA Scenarios and Assumptions

This section describes the scenarios compared in the CBA. The aim is to reflect the delta (difference) between the Reference scenario (where the Solution is not deployed - the orange box in Figure 1) and the Solution scenario (reflecting the proposed deployment of the Solution at applicable locations across ECAC - the green box in Figure 1).

Defining the Reference Scenario has proven to be very challenging because of the assumptions that need to be made regarding the 'ongoing deployments' (blue arrow in Figure 1). To avoid being blocked by this issue the V3 CBA is currently based more on the difference between the current situation (2018) and the Solution Scenario; this is reflected in the following scenario descriptions.

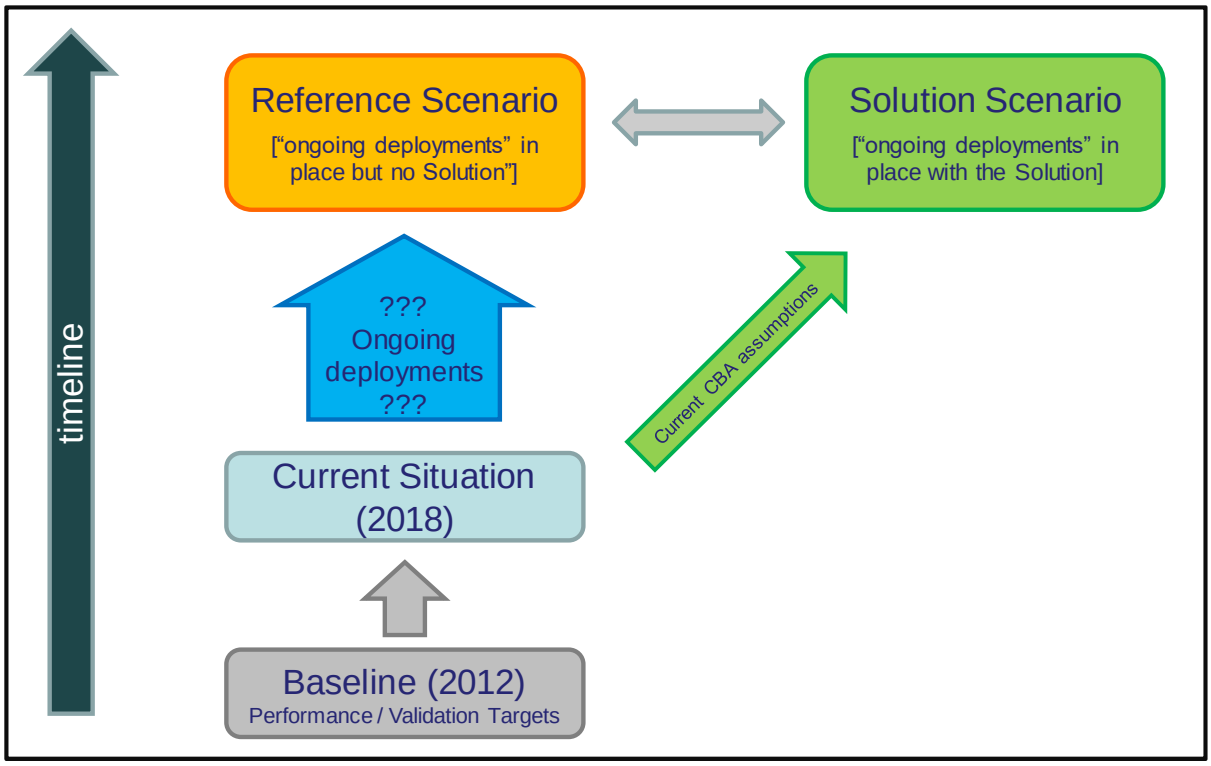

Figure 1: Scenario Overview

The **CBA time-horizon** will cover the period from 2019-2040 (as specified in the PJ19.04 Common Assumptions [5]). During this period, there are several key dates to consider:

- **Start of Deployment** – this is the period where investment costs start to be incurred. Before the Start of Deployment there are no costs or benefits considered in the CBA. The Start of Deployment for this CBA is assumed to start at the same time as the IOC in 2025.

- **Benefit Start: IOC date (Initial Operational Capability)** – this is the time when the ***minimum deployment*** necessary to provide the first benefits occurs. Costs continue after this as further deployment occurs.

- **Full Benefit: FOC date (Full Operational Capability)** – this is the time when the ***maximum deployment***[5] occurs and the full benefits are realised. Investment costs are considered to end here although ongoing operating cost impacts are considered.

- **After FOC** – the Solution is in place and the full benefits are received each year until the end of the working life of the solution.

Investment costs are spread linearly between the Start of Deployment and FOC dates.

3.5.1 Reference Scenario

The CBA Reference Scenario needs to describe the future situation without the Solution deployed (it is NOT a baseline considering today's situation). Assumptions need to be made about what else (other Solutions, etc.) will already be deployed at the time in the future when the Solution will be available for deployment.

The Reference Scenario for the CBA considers the entire ECAC area (acknowledging that US will also be equipping).

Within the Reference Scenario it is assumed that the following pre-requisites are in place:

- all civil aircraft weighting more than 5.7 tons MTOM and/or capable to carry more than 19 passengers in ECAC airspace are currently equipped with TCAS II.
- hybrid surveillance is enabled by both current TCAS II and in the solution.

3.5.2 Solution Scenario

Two CBA Solution Scenarios are considered describing two options for the deployment of the solution:

1. **No mandate** implying that no retrofit is expected except for some Business Aviation (BA) A/Cs (to be more protected).

   Full Operations, meaning that all relevant aircraft (A/Cs) equipped, depend on factors like aircraft replacement, working life of TCAS II, number of years industry will support current TCAS II, capacity to produce new ACAS Xa by Avionics industry.

2. **Mandate in 2030** with 16 months replacement based on TCAS II experience (retrofitting).

   Possibly, for long-haul Aircraft flying to US airports with parallel runways it might be mandatory or at least highly desirable to be equipped. The assumption taken in the cost calculation is that Airlines aware of the mandate to come will start retrofitting their fleet as from the IOC date.

The Solution Scenarios assume that in addition to the Reference Scenario the following applies:

- All Aircraft weighting more than 5.7 tons MTOM and/or capable to carry more than 19 passengers in ECAC airspace will start becoming equipped with ACAS Xa from 2025;

[5] Where ***maximum deployment*** means deploying the Solution in all the locations where it makes sense to deploy it (i.e. it does not mean it has to be deployed everywhere)

- The **Initial Operations**, i.e. the initial date when enough A/C to get benefits are equipped, is **2025.**

3.5.3 Assumptions

Discount rate

The CBA uses 8% as the discount rate to calculate the Present Value (PV) for all stakeholders.

Time-Horizon

The CBA covers the period from 2019-2040 (as specified in [5]).

Number of units

Scenario feature		Year 2018	Year 2020	Year 2030	Year 2040	Source
ECAC traffic ('000 # flights) in line with [5][6]		10 817	11 259	13 846	16 200	STATFOR
Equipage rate 2017[7]		100%			See Section 7	EUROCONTROL PRISME and stakeholder validation
	TCAS #	10 062				
Applicability: Number of locations where Solution is deployed (# OEs)	Area Control Centres (ACCs)	63				EUROCONTROL ACE Report [14]
Impacted traffic, i.e. experiencing the benefits from the Solution(s)	'000 # IFR flights per year	All ECAC traffic				ECAC Traffic above
	'000 # IFR flight hours per year	No benefits are based on flight hours				

Table 4: SESAR PJ.11-A1 CBA Solution Scenario

[6] Traffic forecast from STATFOR [8] comprises Scheduled, Charter, Cargo, Low cost, Business Aviation

[7] The number of A/Cs comprise: Mainline 5471 A/Cs; Regional 1000 A/Cs, Business Aviation 3591, (source: CBA model for European ATM Master Plan 2019)

4 Benefits

The key benefit of ACAS Xa is to improve performance of current safety net (TCAS II) by solving more Near Mid-Air Collisions than current TCAS II and reducing unnecessary alerts while providing the same procedures and operational interaction as current TCAS II.

The benefit Impact mechanisms (shown in Figures 3 and 4) highlight the benefits expected from Solution PJ11-A1 for the main stakeholders ANSPs and Airspace Users:

Safety Benefits:

- ACAS Xa will solve more NMACs than current TCAS II. This benefit is evaluated using the proportion of NMACs avoided.

  The results of the ongoing rerun of validation exercise EXE05 provide a general reduction of 16% in NMAC, on one model, when all the fleet is equipped.

  When looking at specific layers in the airspace, however, there is no benefit in en-route. There can even be more NMACs in some layers in the transition period, when an ACAS Xa equipped aircraft meets a TCAS II equipped aircraft. These issues for particular configurations are being investigated, but may slow the acceptance of the system by EASA.
- Improved performance on current safety net (TCAS II) by reducing unnecessary alerts while providing the same procedures and operational interaction as current TCAS. The results of the ongoing rerun of EXE05 provide a general reduction of at least 70% of unnecessary RAs, on one model, when all the fleet is equipped.

Cost efficiency

- Reduction of investigation due to fewer NMAC and RA investigations. Data suggests that ACAS Xa would only trigger 50 to 60% of the so-called nuisance or compatible RAs compared to TCAS II. At this stage, however it is not possible to estimate a monetary benefit as ACAS Xa may generate other types of nuisance alerts. A possible reduction of “nuisance or compatible RAs” can be expected when more than 80% of the fleet is equipped.
- Reduction in number of “go around” for airspace users.

Capacity

- Reduction of TCAS II unnecessary alarms and so reduction of the possibility of knock-on conflicts due to unnecessary RA induced manoeuvres. In addition, the reduction in number of go-arounds will avoid a decrease in capacity at airports. The evidence available to evaluate this benefit is insufficient to quantify it in the CBA.

HP benefit:

- Reduction of workload to flight crews (due to unnecessary RAs) and increased flight crew trust in ATM system alerts The data available to evaluate these benefits is insufficient to quantify it in the CBA.

In addition, there is an important Interoperability benefit between US and ECAC flights as the FAA is currently evaluating operationally ACAS Xa for commercial flights.

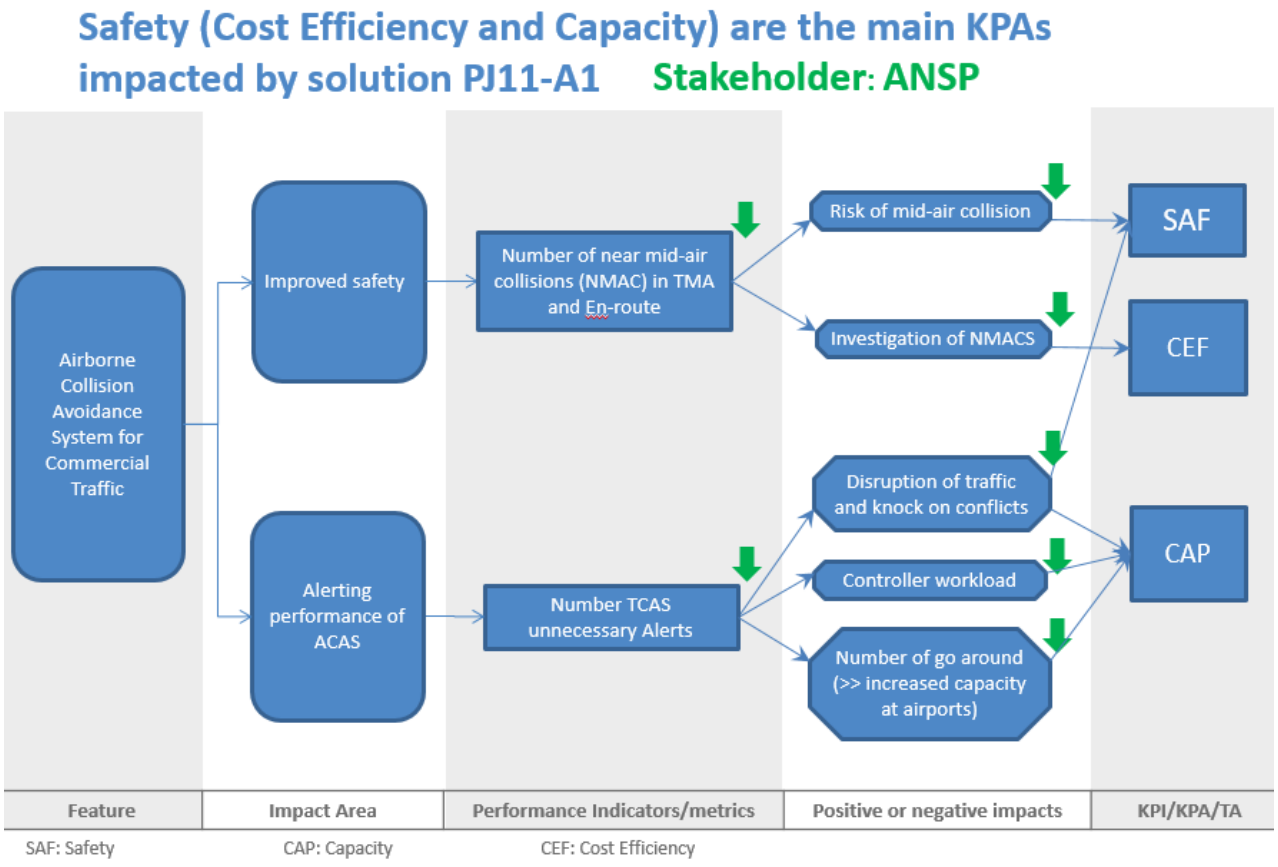

Figure 3: Benefit Impacts for ANSP

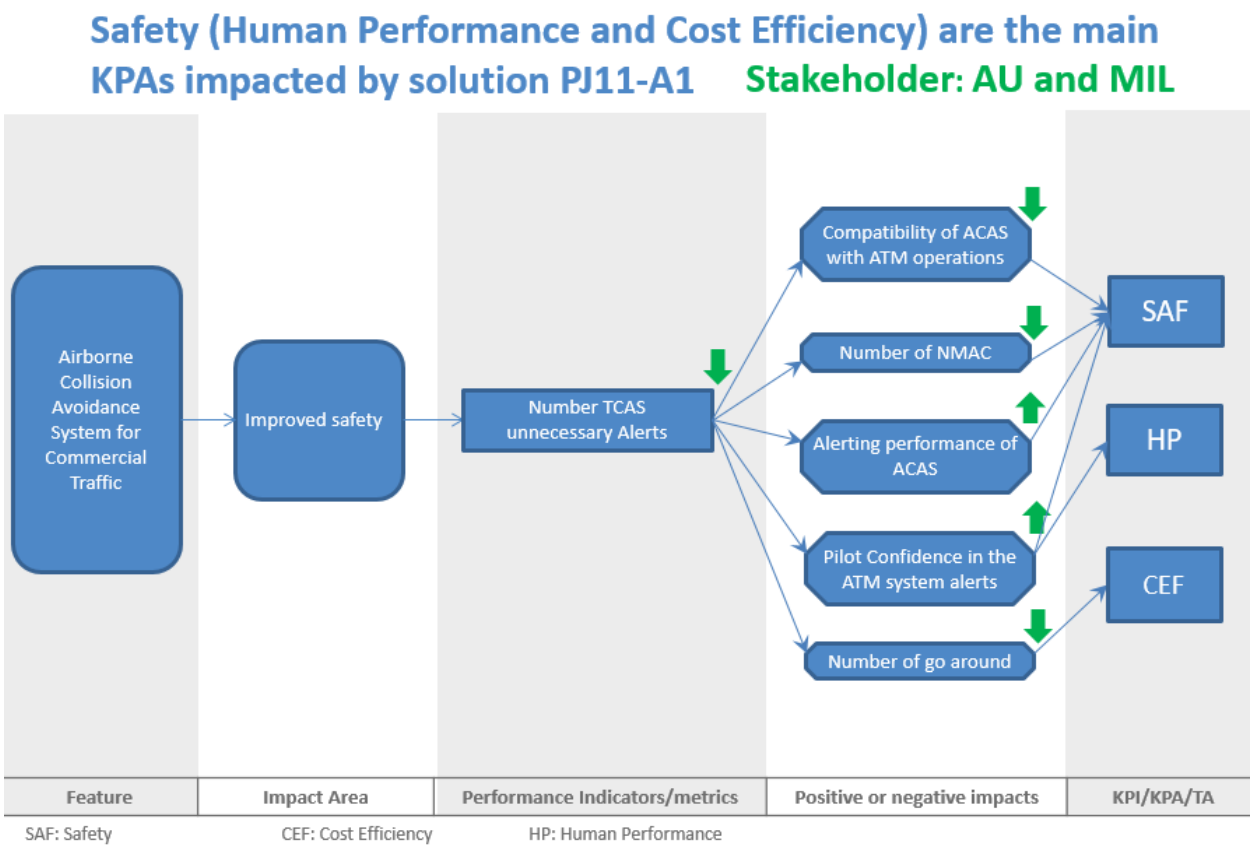

Figure 4: Benefit Impacts for Airspace Users

5 Cost assessment

5.1 ANSPs costs

The CBA considers the investment costs of upgrading investigation and analysis of Operations software (software that reproduces what occurred) and necessary investigators' training (approximately 1 week). The investment is of relevance for ANSPs/ACCs who:

1. perform investigations or provide data for outsourced investigations
   In principle, all ANSPs/ACCs should carry out their own investigations. Some of them however may outsource specific cases but that should not be generalised.
2. display RAs on the controller working position
   ANSPs/ACCs may decide or not to invest to display RAs on the controllers working position. Currently, despite awareness campaigns in 2007/2008, only five ANSPs have the necessary software for RA display. Based on Expert judgement this cost assessment assumes that a maximum of eight ACC will get the necessary software for RA displays.

All ACCs will need to invest in the upgrade of software to collect ACAS RA on the ground (change of format of RA downlink messages).

5.1.1 ANSPs cost approach

5.1.2 ANSPs cost assumptions

The following cost assumptions are taken:

- Upgrade of operations software: **30 man-days investigation software** (additional HMI and data presentation), this involves upgrade of operations software (additional HMI and data presentation) carried out by a computer scientist with medium experience in the field and **3 days of training** of ACAS experts possibly also trainees.

  Cost: software development @ 700€/day and training ACAS experts @ 900€/day.

- Upgrade of software to collect ACAS RA on the ground: **5 man-days** for interpreting the ACAS Xa format.

  Cost: software development @ 700€/day

- The upgrade for ANSPs / ACCs is a one off cost assumed to take place simultaneously in all ACCs at IOC date in 2025.

- Maintenance cost is assumed to not change with ACAS Xa

5.1.3 Number of investment instances (units)

Airport				TMA			ACC		
HC	HS	LC	LS	H	M	L	H	M	L
N/A				N/A			8/63[8]		

Table 5: Number of investment instances - ANSPs

5.1.4 Cost per unit

Cost category	Airport				TMA			ACC		
€	HC	HS	LC	LS	H	M	L	H	M	L
Pre-Implementation Costs										
Implementation costs (investigation)								23 700		
Implementation costs (RA display)								3 500		
Operating costs										

Table 6: Cost per Unit - ANSP

5.2 Airport operators costs

Civil and Military Airport operators are not required to invest in any Enablers for this Solution.

5.3 Network Manager costs

The Network Manager is not required to invest in any Enablers for this Solution.

5.4 Airspace User costs

Civil Airspace Users are required to invest into the acquisition of a new ACAS Xa software and hardware box.

[8] Only 8 ACCs are assumed to invest to get the necessary software for RA display. However, all 63 European ACCs will need to invest to perform investigations or provide data for outsourced investigations.

5.4.1 Airspace User cost approach

5.4.2 Airspace User cost assumptions

- The AUs cost estimate includes: software cost and upgrades; hardware cost of new box; cost of participation to MOPS (Minimum Operational Performance Standards); cost of certification (EASA);
- Other cost - all aircraft > 5.7 t MTOM and/or over 19 passengers seats need to be equipped
- Operating cost (maintenance) is assumed to be unchanged vis à vis TCAS II
- Equipage rate assumed to be linear between IOC 2025 and FOC 2031
- Forward fit end date is set to 2035 assuming that after 10 years of operations the tool will a fully integrated in new aircraft

Two scenarios:

- **Scenario 1 assumes natural replacement** with forward fit. Only new A/C will be equipped. All the fleet for Scheduled Airlines and Business Aviation is taken into account.

  Full Operations i.e. all relevant A/Cs are equipped, depends on aircraft replacement, working life of TCAS II, number of years industry will support current TCAS II. However assuming that TCAS II system (latest version 2008) has a life expectancy of 30-50 years[9], the cost assessment focuses on new A/Cs only.
- **Scenario 2 assumes a mandate in 2030** where relevant A/Cs will need to be equipped. This implies costs for new A/Cs and retrofit cost for existing A/Cs.

5.4.3 Number of investment instances (units)

Scheduled Airlines (SA)		General Aviation (GA)		Business Aviation (BA)		Rotorcraft	
Ground locations (e.g. FOCs)	Airborne (air vehicles)	Airborne IFR vehicles	Airborne VFR vehicles	Ground locations	Airborne (air vehicles)	Ground locations	Airborne (air vehicles)
N/A	6471	N/A	N/A	N/A	3591	N/A	N/A

Table 7: Number of investment instances - AUs

[9] ACAS Expert judgement

5.4.4 Cost per unit

The cost range provided below is based on two sources:

1) A Report [13] of a contract award for TCAS/ACAS by the FAA made in 2008, inflated to 2018 prices.
2) A high level assessment [15] of Implementation of TCAS II version 7.1 in European airspace where replacing TCAS II version 7.0 units was estimated at a cost of up to $US 75 000 (2009).

Cost for forward fit (2018 prices)

	Range	
Cost category	**Low**	**High**
Pre-Implementation Costs	n/a	n/a
Implementation costs	**€ 83 000** (US$ 93 000)	**€ 145 000** (US$ 163 000)
Operating costs	n/a	n/a

Cost for retrofit (2018 prices)

	Range	
Cost category	**Low**	**High**
Pre-Implementation Costs	n/a	n/a
Implementation costs – Additional adaptation cost	**€ 52 000** (US$ 58 500)	**€ 73 000** (US$ 81 500)
Total Implementation Cost	**€135 000**	**€218 000**
Operating costs	n/a	n/a

Table 8: Cost per unit – AUs

5.5 Military costs

Military Airspace Users are required to invest into the acquisition of a new ACAS Xa software and hardware box. The costs have not yet been estimated due to insufficient data.

5.5.1 Military cost approach

5.5.2 Military cost assumptions

5.5.3 Number of investment instances (units)

Military	
Ground facilities	Air vehicles

Table 9: Number of investment instances - Military

5.5.4 Cost per unit

Cost category	Military	
	Ground facility	Air vehicle
Pre-Implementation Costs		
Implementation costs		
Operating costs		

Table 10: Cost per unit - Military

5.6 Other relevant stakeholders

Other relevant stakeholders are not identified.

6 CBA Model

The CBA Model used to calculate the costs is the Model proposed by PJ19-4 for CBAs of individual solutions. Note that this model is a working draft.

s.6.2.41_for_PJ11_v6.xlsm

6.1 Data sources

See chapter 10

7 CBA Results

The CBA results shown in this Section are the monetary results of the cost assessment. The benefits have been evaluated qualitatively in terms of the proportion of near mid-air collisions avoided (See Section 4).

1. **Scenario 1: deployment with no mandate, forward fit only, 2019-2040**

Cost (M€)	Low	High
ANSP	1.4	1.4
Airspace Users		
Business Aviation	128	223
Scheduled Airlines	430	752
Total Undiscounted	**559**	**976**
Discounted (8%)	225	392

Note that in this scenario by 2040, only approximately 70% of the fleet would be equipped.

2. **Scenario 2: deployment with mandate in 2030 with 16 months implementation, 2019-2040**

Cost (M€)	Low	High
ANSP	1.4	1.4
Airspace Users		
Business Aviation	600	934
Scheduled Airlines	1 362	2 152
Total Undiscounted	**1 963**	**3 087**
Discounted (8%)	883	1 382

In this scenario, the full equipage of the fleet would be achieved by 2031.

8 Sensitivity and risk analysis

The wide cost interval estimated for the equipage cost indicates that the cost for deploying this solution in ECAC could easily reach values above 1 B€, especially in a scenario with mandate A total cost of this magnitude needs to be balanced by clear and robust evidence on the Safety Benefits that this solution can bring to ECAC. This evidence should be provided by the next validation exercise of the solution planned for the end of 2019.

9 Recommendations and next steps

Considering the wide range of values possible for the cost of deploying this solution and the potentially very high cost of deploying it in ECAC, the following recommendations are made for future development of this solution:

1. To obtain more robust evidence of the safety benefits of this solution in ECAC. The validation exercise planned for Q4 2019 should address this recommendation.

2. To reduce the uncertainty in the equipage costs estimates. For this, the contribution from Industry would be needed.

10 References and Applicable Documents

10.1Applicable Documents

This CBA complies with the requirements set out in the following documents:

[1] SESAR 2020 Project handbook, Ed. 00.09.07, 31st October 2016

[2] 16.06.06 D26-04, Guidelines for Producing Benefit and Impact Mechanisms, Edition 03.00.01

[3] 16.06.06 D26, Methods to Assess Costs and Monetise Benefits for CBAs, Edition 02.00.01

[4] 16.06.06 D26-08, CBA Quality Check-List, Edition 02.00.01

10.2 Reference Documents

The following documents were used to provide input / guidance / further information:

[5] PJ19, D4.0.1, SESAR 2020 Common assumptions, Edition 01.00.00, 17 May 2018

[6] SESAR 16.06.06, D48, SESAR Business Case Example – Remote Tower, Edition 00.01.02

[7] SESAR C.02-D110, Updated D02 after MP Campaign, Edition 00.01.00

[8] STATFOR European Aviation in 2040 Challenges of Growth, 2018

[9] ACAS X CONOPS, V2, FAA, April 18, 2013

[10] PMP PJ11, Ed. 00.00.02, 31 March 2017

[11] ICAO Document 9854, “Global Air Traffic Management Operational Concept”, First Edition 2005

[12] ICAO Annex 10, vol. IV, “Aeronautical Telecommunications - Surveillance and Collision Avoidance Systems”, Fourth Edition, July 2007

[13] Archived Report on a contract award for TCAS/ACAS by the FAA https://www.forecastinternational.com/archive/disp_pdf.cfm?DACH_RECNO=624

[14] ATM Cost-Effectiveness (ACE) Benchmarking report : https://www.eurocontrol.int/sites/default/files/2019-06/ace-2017-benchmarking-report.pdf

[15] Implementation of TCAS II version 7.1 in European airspace, High-level impact assessment. EUROCONTROL, March 2009

[16] VALR-ACASX-HP Validation Report for the Assessment of Human Performance aspects of ACAS Xa, SESAR 1 Project 04.08.01, deliverable D95

[17] GEN-ACASX-Acceptability SESAR vision of European acceptability criteria for ACAS Xa development, SESAR 1 Project 04.08.01, deliverable D101

10.3 Other References

[18] EATMA, dataset 19, January 2017

[19] EUROCONTROL ACAS Expert interview, January 2017

-END OF DOCUMENT-