SESAR Solution PJ11-A4 V1 OSED (TSAA+)

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CAPITO

PJ.11 CAPITO

This V1OSED 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

The purpose of this V1 OSED document is to define SA+ capability concept, describe intended operational environment with its characteristics, and describe the SA+ operating method. This OSED is based on initial OSED prepared to be used as a prerequisite for V1 validations which was refined based on validation results.

In addition to updated content of Initial OSED, this version contains also the description of typical Use Case and Benefit Impact Mechanism (BIM) diagram.

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1 Executive Summary

The purpose of this V1 OSED document is to define SA+ capability concept, describe intended operational environment with its characteristics, and describe the SA+ operating method. This V1 OSED is refined initial OSED is refined based on validation results.

The SESAR solution under the scope of this document is SA+, further referred as TSAA+. SA+ capability refers to enhancement of already standardized ADS-B IN Traffic Situational Awareness with Alerts **(TSAA)** application enhanced to use information about intruder RA (Resolution Advisory), and indicate it to Pilot. Such enhancement is referred as TSAA+ and its operational concept is built upon TSAA.

TSAA+ aims to address mixed equipped encounters, e.g. encounters involving TCAS-equipped and non-TCAS-equipped aircraft which are one of the remaining sources of mid-air collision **(MAC)** risk. TSAA+ is intended to provide timely alerts of qualified airborne traffic in the vicinity of ownship in order to increase flight traffic situation awareness, and if TCAS II-equipped traffic is issuing an RA (against ownship or any other traffic), then the information about RA will be passed to the flight crew. TSAA+ application is intended to reduce the risk of NMAC or MAC by aiding in visual acquisition, and to avoid TSAA+ pilot to manoeuvre against RA of TCAS II-equipped aircraft (e.g. idea is NOT to manoeuvre).

This document does not contain safety and performance requirements, as well as interoperability aspects, which are not required for V1 phase, and will be defined in the next maturity phase. In addition, interoperability with other surveillance systems (e.g. TCAS I or TAS) with which TSAA+ may interoperate is out of the scope of this solution.

2 Introduction

2.1 Purpose of the document

The purpose of this V1 OSED document is to define SA+ capability concept, describe intended operational environment with its characteristics, and describe the SA+ operating method

2.2 Scope

This is the V1 OSED for Solution PJ.11-A4 (SA+ capability) for V1 phase. The TSAA+ definition or system description are proposals relevant for initial V1 maturity level and may be subject to change in next iterations of this document.

This document does not contain safety and performance requirements, as well as interoperability aspects, which are not required for V1 phase, and will be defined in the next maturity phase. In addition, interoperability with other surveillance systems (e.g. TCAS I or TAS) with which TSAA+ may interoperate is out of the scope of this solution.

2.3 Intended readership

The intended audience for this document are members of PJ11-A4 solution and PJ11 members in general. At a higher programme level, the Content Integration project (PJ19) who is responsible for coordination and integration of solutions, as well as development of validation strategy with appropriate validation targets, would find contained information useful.

In addition, General Aviation, Rotorcraft, Military airspace users, as main stakeholders, may have an interest in this document.

2.4 Background

In the United States (U.S.) National Airspace System (NAS) alone, there has been an average of 12.4 mid-air collisions of General Aviation (GA) aircraft per year resulting in an average of 19.1 fatalities annually from 1997-2008[44]. Between 2000 and 2010, 9% of mid-air collisions involved at least one rotorcraft [38]. These collisions have far-reaching consequences, including mobilization of crash, fire, and rescue services. In some cases, delays may be introduced into the system, and workload for flight crews and controllers may increase in the immediate aftermath. There are insurance, legal and regulatory ramifications. The number of incidents where aircraft come uncomfortably close (ICAO Air Proximity Hazard [AIRPROX] which include Near Mid-Air Collisions [NMAC]) is much higher than the number of incidents resulting in collisions. From 1987-2012 there were 4663 NMAC reports involving General Aviation aircraft, which can be considered precursors to a mid-air collision accident [45].

In European Aviation Safety Agency (EASA) Member States in the period 2006-2010 for aircraft below 2250kg, there was an annual average of 1158 accidents and 149 fatal accidents, with 238 fatalities on board [46]. Slightly more than half of the accidents were airplanes, about one quarter were gliders and about one tenth were helicopters. Fatal accidents were distributed as: airplane 41%; microlight[1] 23%, glider 18%; other 9%; helicopter 7%; gyroplane 2%; dirigible 1%; balloon 1%. The majority of fatal accidents were categorized as “Loss of Control in flight” and “Low altitude”. An average of about seven fatal accidents per year were categorized “Mid-air proximity or collisions”. This category has a noticeably higher incidence for gliders than for helicopters and airplanes.

Looking at MAC historical data ([47]), since 1990 there have been 4 MAC involving civilian aircraft, a Military Fixed Wing aircraft and 2 MAC involving a Military Helicopter. More importantly looking at close encounter incidents not developing into a MAC, only in UK from 2000 to today have been reported to UK AIRPROX Board a total of 1151 risk-bearing AIRPOROX incidents (Cat A or B), out of which 337 (30%) have involved military aircraft (fixed wing or helicopter) and civil aircraft ([49]).

Traffic Alert and Collision Avoidance System (TCAS) technology has reduced the number of mid-air collisions involving air transport aircraft [50], but a similar reduction in mid-air collisions has not occurred in general aviation despite the availability of similar avionics and services. While many air transport aircraft were required to equip with TCAS systems, no such mandate has occurred for general aviation aircraft. General aviation aircraft owners and operators make a cost-benefit decision whether to equip with traffic awareness or alerting systems or not to equip at all.

As operational experience with the TCAS system has increased and studies have shown the safety benefits to be obtained, the desire to equip helicopters with ACAS has grown (although it were often the traffic display aspect of ACAS that appealed rather than the direct safety net provided by RAs), as witnessed by a EUROCONTROL safety study on TCAS II on Helicopters published in 2008 ([51]). The safety study was complemented by some flight trials and resulted in voluntary equipage on few helicopters operating to the oil rigs on the North Sea. Indeed, questions have been left open by the study (e.g. considered helicopters in forward flight only, ACAS Climb inhibits, Vertical rates limitations, Multiple encounters, effect on RF environment) which did not follow up into subsequent studies.

Traffic Situation Awareness with Alerts (TSAA) is an Automatic Dependent Surveillance- Broadcast (ADS-B) IN application that is intended to reduce the number of mid-air collisions and near mid-air collisions involving general aviation aircraft. TSAA provides voice annunciations to flight crews to draw attention to Alerted Traffic. It also adds visual cues to the Traffic Display of underlying basic traffic situation awareness applications (e.g., Enhanced Visual Acquisition [EVAcq] or Enhanced Traffic Situational Awareness During Flight Operations [AIRB], see [4]) in installations where a Traffic Display is available. The TSAA application uses ADS-B information, and where available Automatic Dependent Surveillance-Rebroadcast (ADS-R) and Traffic Information Service-Broadcast (TIS-B) information to provide the flight crew with indications of nearby aircraft in support of their see-and-avoid responsibility.

In the European environment, the UAT data link is not used and TIS-B and ADS-R will not be implemented. For this reason, in the remaining of the document we will only refer to ADS-B single link implementations (i.e. 1090 MHz Mode-S Extended Squitter) and ADS-B as the sole surveillance source used by TSAA/SA+ applications.

[1] In some countries known as ultralight.

TSAA surveillance application has been studied by FAA, and its specifications are contained in RTCA DO-317B (Minimum Operational Performance Requirements) and DO-348 (Safety and Performance Requirements) and their EUROCAE equivalents ED-194A and ED-232 respectively.

The TSAA equipment is expected to be less expensive than existing Traffic Advisory Systems (TAS) and TCAS I systems. The TSAA application will use different logic to provide a similar safety benefit to airspace users. By reducing the cost of a traffic system, it is expected that more general aviation aircraft owners and operators will voluntarily choose to install TSAA equipment thus reducing the risk of mid-air collisions.

The TSAA equipment uses passive surveillance technologies, requiring no interrogations. It can potentially take advantage of the antenna(s) and installation effort associated with an ADS-B OUT installation. When installed in conjunction with an ADS-B OUT system, TSAA will lead to safety benefits and could provide an incentive to voluntarily equip sooner with an ADS-B system prior to mandated ADS-B OUT equipage ([52]).

ACAS Xp is a specific GA targeted version of the new airborne collision avoidance system developed by FAA under name ACAS-X. It is based on passive ADS-B surveillance of surrounding traffic. As ACAS Xp is at the stage of concept development, the information provided in this document is very high-level and the comparison is based on the set of assumptions about ACAS Xp application.

SESAR1 Project 9.47, as a preliminary evaluation of future ACAS Xp performance, has compared the performance of GA-intended Traffic Situational Awareness with Alerts (TSAA) system and its alerting capabilities with ACAS Xa (primarily addressing CAT needs) model modified to use passive surveillance only; however without any modifications for GA. Selected TSAA-tailored and US-airspace test vectors of the MOPS were run through both TSAA and ACAS X models, focusing on evaluation of how the alerting system behaves when it IS EXPECTED to alert, and how it does behave when it IS NOT EXPECTED to alert (operational performance).

Nevertheless, TSAA application has been designed (and implementations are verified) against a set of test encounters which have been derived from the analysis of US airspace MAC and NMAC historical data, and its operational suitability and effectiveness in the European airspace is yet undetermined. It is now possible to take advantage of European recent radar track data and ACAS-X ongoing encounter modelling activities for assessing TSAA within European airspace environment from an operational point of view.

One of the remaining sources of mid-air collision risk is encounters between aircraft that are equipped with Traffic Alert and Collision Avoidance System (TCAS) and non-TCAS-equipped General Aviation (GA) aircraft. Previous studies conducted by MIT [42] showed that if the GA pilot is made aware of the Resolution Advisory raised by the TCAS equipped intruder, by adopting a responsive coordination strategy the risk ratio would be always lower than when the system only responds to TCAS, and no coordination. In this context TSAA would help the GA pilot in triggering attention to potential risk of collisions and TCAS intruder visual acquisition, hence in increasing response rate and reaction time, which are factors contributing positively in risk ratio reduction.

For this reason, it is expected that enhancing TSAA application to use information about intruder RA (Resolution Advisory), and indicate it to Pilot (SA+ capability), could further reduce risk of MAC and NMAC.

Equipping GA aircraft with a full collision avoidance system such as ACAS-Xp, providing Resolution Advisories and suitable coordination, may further reduce the mid-air collision risk.

2.5 Structure of the document

Sections 1 and **2** provides are dedicated to overview summary, scope description and more details about the background of the problematics.

Section 3 details about operational environment, its operational and technical characteristics, roles and responsibilities as well as description of new operating method and its comparison with previous one.

Section 4 is assigned for SPR-INTEROP which is not applicable for this maturity phase.

Section 5 provides list of reference material.

Appendix A is dedicated for Cost and Benefit Mechanisms.

Appendix B provides an overview of Encounter Categories for TSAA.

Appendix C provides a summary of existing and under development Encounter Models.

Appendix D provides an overview of relationship with other alerting applications.

Appendix E provides the mapping of ED-232/DO-348 TSAA OSED with this document.

2.6 Glossary of terms

Term	Definition	Source of the definition
AIRCRAFT	An aircraft is any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.	ICAO Annex 1, Annex 6 Part I
AEROPLANE	A power driven heavier than air aircraft, deriving its lift in flight chiefly from aerodynamic reactions on surfaces which remain fixed under given conditions of flight.	ICAO Annex I, Annex 6
AIRPROX	A situation in which, in the opinion of a pilot or a controller, the distance between aircraft as well as their relative positions and speed have been such that the safety of the aircraft involved was or may have been compromised	ICAO
AIR-REPORT	A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.	ICAO Annex

Automatic dependent surveillance broadcast (ADS-B)	A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.	ICAO DOC 10019
General Aviation Aeroplanes (GAA)	General Aviation (GA) is defined by ICAO as "all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire". This encompasses a wide range of activity: • Pilot training • Business aviation • Recreation including balloon, glider and model aircraft flying • Agriculture including crop spraying • Mail and newspaper deliveries • Transport of dangerously ill people and of urgently needed human organs, medical equipment and medicines • Monitoring ground traffic movements from the air • Civil search/rescue • Law enforcement including operations against smuggling • Aerial survey including photography for map making and pipeline and power cable patrols • Pollution control and fire fighting • Flying displays and aircraft platforms: • Fixed wing • Rotary wing • Unconventional (e.g. balloons, airships, gliders, autogyro) In the context of PJ11-A4 “General Aviation aeroplanes” will indicate Fixed Wing platforms used for GA activities. This PJ11-A4 GA definition will include the EASA Safety Categories: “Aerial Work/Part SPO Aeroplanes” and “Non-Commercial Operations Aeroplanes”.	PJ11-A4
Rotorcrafts (R)	In the context of PJ11-A4 with Rotorcrafts (or Helicopters) will indicate a rotary wing platform of any size (from Ultra-light to Medium, Heavy) used for GA, Commercial, Aerial Work, Customs, Police activities, including military helicopters as part of their operations in non-segregated airspaces.	PJ11-A4

	This PJ11-A4 GA definition will include the EASA Safety Categories: “Commercial Air Transport Helicopters”, “Aerial Work/Part SPO Helicopters” and “Non-Commercial Operations Helicopters”.	
State Aeroplanes (StA)	In the context of PJ11-A4 “State Aeroplanes” will indicate any Military, Police, Customs Fixed Wing platform flying in non-segregated airspace, excluding Transport Type aircraft. Example of aeroplanes considered in this category are: military fast jets, military trainers, bizjet used e.g. for: police, custom, search & rescue, VIP transport, hospital transport, etc.	PJ11-A4
Near Mid Air Collision	Near Mid Air Collision (NMAC) occurs when two aircraft come within 100 feet vertically and 500 feet horizontally	TCAS MOPS (DO-185)

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
1090ES	Mode S Extended Squitter
A/C	Aircraft
ACAS	Airborne Collision Avoidance System
ACAS Xa	ACAS X – Active
ACAS Xp	ACAS X – Passive
ACE	Active Coordination Emulation
ADD	Architecture Definition Document
ADS-B	Automatic Dependent Surveillance – Broadcast
ADS-R	ADS-B Rebroadcast
AIRB	Basic Airborne Situation Awareness
AMC	Acceptable Means of Compliance
ARES	Airspace Reservation/Restriction
ASA	Aircraft Surveillance Applications
ASIAS	Aviation Safety Information Analysis and Sharing
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control

Acronym	Definition
ATM	Air Traffic Management
ATS	Air Traffic Services
AU	Airspace Users
AVAL	European encounter model based on 2007/2008 radar data
CA/CAS	Collision Avoidance (System)
CAT	Commercial Air Transport
CATI	Cockpit Annunciator for Traffic Information
CAZ	Collision Airspace Zone
CDTI	Cockpit Display of Traffic Information
CPA	Closest Point of Approach
DOD	Detailed Operational Description
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
EASA	European Aviation Safety Agency
ECAC	European Civil Aviation Conference
EVAcq	Enhanced Visual Acquisition
FAA	Federal Aviation Administration
FLARM	Traffic and collision warning system for GA
GA	General Aviation
GAT	General Air Traffic
GAA	General Aviation Aeroplane
GNSS	Global Navigation Satellite System
HAZ	Hazard Zone
HAZ'	No Hazard Zone
HMD	Horizontal Miss Distance
IA	Intersect Angle
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
IRS	Interface Requirements Specification
LLEM	Lincoln Lab Encounter Model

Acronym	Definition
LPAT	Low Power ADS-B Transceiver
INTEROP	Interoperability Requirements
MAC	Mid-Air Collision
MOPS	Minimum Operational Performance Standards
MTOM	Maximum Take-Off Mass
MTOW	Maximum Take-Off Weight
MTTA	Military Transport-Type Aircraft
NAS	National Airspace System
NAT	Nearby Airborne Traffic
NMAC	Near Mid-Air Collision
NTSB	National Transportation Safety Board
OPA	Operational Performance Assessment
PAZ	Protected Airspace Zone
PCAS	Portable Collision Avoidance System
PRs	Performance Requirements
R	Rotorcraft
RA	Resolution Advisory
RHV	Relative Horizontal Velocity
RTCA	American Standardisation body that produces MOPS for TCAS
RVV	Relative Vertical Velocity
RWY	Runway
OFA	Operational Focus Areas
OAT	Operational Air Traffic
OSED	Operational Service and Environment Definition
StA	State Aeroplane
SA	Situation Awareness
SA+	Enhanced Situation Awareness (TSAA+)
SBS	Surveillance and Broadcast Services
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.

Acronym	Definition
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SPR	Safety and Performance Requirements
SUA	Special Use Airspace
SUT	System Under Test
SVFT	Special Visual Flight Rules
TA	Traffic Advisory
TABS	Traffic Awareness Beacon system
TAD	Technical Architecture Description
TAS	Traffic Advisory System
TCA	Traffic Caution Alert
TCAS	Traffic Alert and Collision Avoidance System
TD	Traffic Display
TIS	Traffic Information Service
TIS-B	Traffic Information Services – Broadcast
TRAMS	TCAS RA Monitoring System
TS	Technical Specification
TSA	Traffic Situational Awareness
TSAA	Traffic Situation Awareness with Alerts
TSAA+	Enhanced TSAA (refer to SA+)
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VMD	Vertical Miss Distance
VP	Verification Plan
VR	Verification Report
VS	Verification Strategy
UAT	Universal Access Transceiver

Table 2: List of acronyms

3 Operational Service and Environment Definition

3.1 SESAR Solution PJ11-A4: SA+ a summary

The SESAR solution under the scope of this document is SA+, further referred as TSAA+. From EATMA point of view, the capability addressed by PJ.11-A4 is **Mid-Air Collision Avoidance**.

SA+ capability refers to enhancement of already standardized ADS-B IN Traffic Situational Awareness with Alerts **(TSAA)** application enhanced to use information about intruder RA (Resolution Advisory), and indicate it to Pilot. Such enhancement is referred as TSAA+ and its operational concept is built upon TSAA.

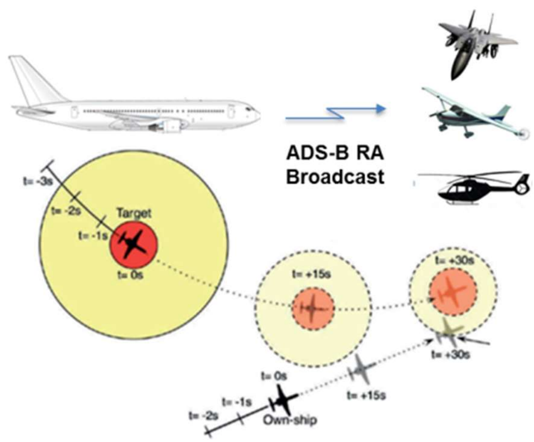


Figure 1: TSAA+ pictorial view

TSAA+ aims to address mixed equipped encounters, e.g. encounters involving TCAS-equipped and non-TCAS-equipped aircraft which are one of the remaining sources of mid-air collision **(MAC)** risks [41]. TSAA+ is intended to provide timely alerts of qualified airborne traffic in the vicinity of ownship in order to increase flight traffic situation awareness, and if TCAS II-equipped traffic is issuing an RA (against ownship or any other traffic), then the information about RA will be passed to the flight crew. TSAA+ application is intended to reduce the risk of NMAC or MAC by aiding in visual acquisition, and to avoid TSAA+ pilot to manoeuvre against RA of TCAS II-equipped aircraft (e.g. idea is NOT to manoeuvre).

The TSAA+ is intended for any civil or military, powered aircraft or rotorcraft which is not under TCAS II mandate. It is intended to operate in any airspace (controlled or uncontrolled) with various traffic density; in IMC or VMC; during IFR or VFR flights; during departure, en-route or approach operations when there is a potential of encounters with commercial, TCAS II-equipped aviation. TSAA+ will only be effective in an airspace where ADS-B Out equipment is installed and operational.

This SESAR solution is from the EATMA point of view addressed under PJ11-A4, Airborne Collision Avoidance for General Aviation and Rotorcraft – ACAS Xp, but since ACAS Xp and TSAA+ are two different capabilities, PJ11-A4 will be most likely split in the near future. For the time being, TSAA+

reference to EATMA and SESAR CONOPS is as defined in the tables below. Once final decision about the solution split is done, the solution description, OI step and enablers will be refined.

This table describes the SESAR Solution under the scope of this document, with reference to the applicable EATMA reference.

SESAR Solution ID	SESAR Solution Title	OI Steps ID ref. (coming from EATMA)	OI Steps Title (coming from EATMA)	OI Step Coverage
PJ11-A4	Airborne Collision Avoidance for General Aviation and Rotorcraft – ACAS Xp SA+ capability	CM-0808-p	Collision Avoidance for General Aviation and Rotorcraft (ACAS Xp)	**Partial** This document covers only SA+ capability of the solution.

Table 3: SESAR Solution PJ.11-A4: SA+ Scope and related OI steps

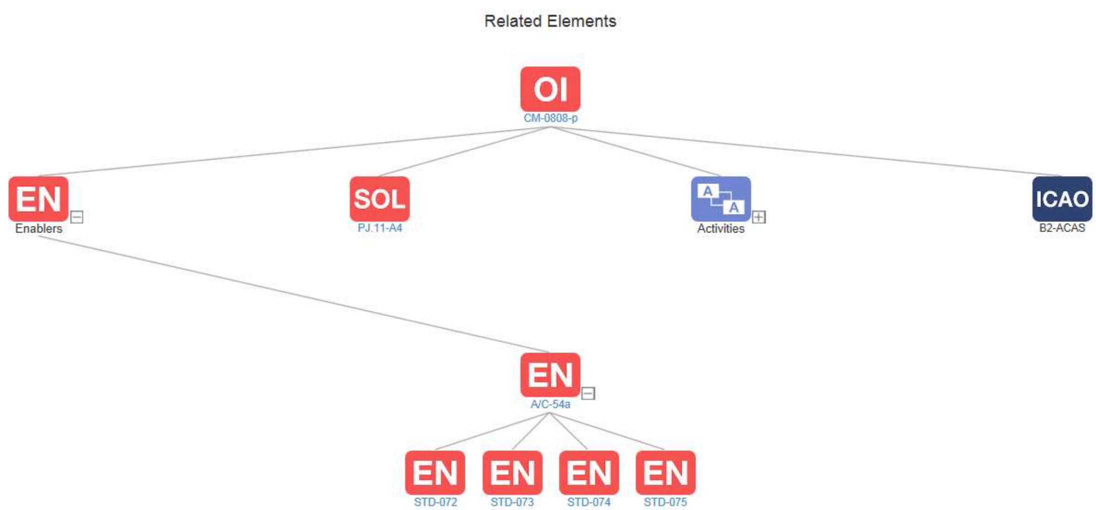


Figure 2: Associated Enablers for OI step CM-0808-p

According to DS18, CM-0808p does not have allocated Key Feature (Suggested SESAR Key Feature to be allocated: Advanced Air Traffic Services), or Capability. This solution is Safety solution and According to Validation Targets 2018, the safety has to be increased by 1,23% (0,7% ER and 0.53% TMA).

Even if in the eATM portal the solution PJ.11-A4 is linked to the solution PJ.11-A1, this solution is independent of other solutions.

High Level CONOPS Requirement ID	High Level CONOPS Requirement	Reference to relevant CONOPS Sections e.g. Operational Scenario applicable to the SESAR Solution
S11-A4-HL-01	Airborne Collision Avoidance for General Aviation and Rotorcraft (ACAS Xp) shall be provided by marking GA/R aircraft capable of responsive coordination (i.e. after receiving an ADS-B squitter that identifies them as an intruder in an ongoing RA on-board of another aircraft, the GA/R aircraft would be aware of the RA direction of the another aircraft, and would use it to determine its own manoeuvre with GA/R adapted advisories).	CONOPS (B.04.02 – D106), v. 01.00.00, section 5.12.1

Table 4: Link to CONOPS

TSAA+ capability due to its low maturity is not yet fully defined in EATMA. Solution model needs to be developed and integrated into EATMA.

3.1.1 Deviations with respect to the SESAR Solution(s) definition

OI Step Code	OI Step title	Deviation
CM-0808-p	Collision Avoidance for General Aviation and Rotorcraft (ACAS Xp)	No deviation

EN Code	EN title	Deviation
A/C-54a	Enhanced Airborne Collision Avoidance (ACAS)	No deviation
STD-072	ACAS Interoperability	No deviation
STD-073	ACAS-Xa MOPS	This EN is not applicable to this Solution
STD-074	MASPS for AFGS / ACAS-coupling	This EN is not applicable to this Solution
STD-075	ACAS-Xu MOPS	This EN is not applicable to this Solution

While checking the eATM portal, the following EATMA element have been identified as possibly applicable to the solution:

- **OI:** AUO-0402: Air Traffic Situational Awareness (ATSAW) during Flight Operations (AIRB)

- **EN:** A/C-26: Airborne Traffic Situational Awareness to support in flight operations (ATSA-AIRB), including reception (ADS-B IN), processing and display.

In addition, OI steps and enablers linked with PJ11-A4 currently do not refer directly to SA+ capability, rather than Collision Avoidance (CA) capability. PJ.11-A4 solution will be most likely split into two, and relevant OIs and enablers will be defined.

Suggested OI title: Enhanced Situational Awareness for non-ACAS equipped aircraft, rotorcraft and military.

The corresponding Change Request will be raised following the Change Request Management process.

3.2 Detailed Operational Environment

3.2.1 Operational Characteristics

Operational interactions per context (NOV-2)	Operating Environment
[Safety Nets] Airborne Collision Avoidance for General Aviation and Rotorcraft - ACAS Xp	**Mixed En-Route/Terminal** High Complexity Low Complexity Medium Complexity Very High Complexity

Comment
This section contains the detailed description of the Operational environment in order to get knowledge of the fundamental operational characteristics that govern the solution addressed in this document. The benefits of TSAA/TSAA+ will differ per: • Airspace class (A-F), • Flight rules (IFR, VFR), • Type of flight (military, general aviation), • Separation provided (all aircraft, IFR from IFR, IFR from VFR, NIL), • Service provided (e.g., ATC, traffic information, flight information). • ADS-B Out equipage of other traffic • TCAS equipage of other traffic It is expected that Safety benefits will be greater in uncontrolled airspaces and in airspace where Air Traffic Services (ATS) are limited. **TSAA/TSAA+ Intended Aircraft** • Powered A/C not under TCAS II mandate; • Civil & State Aeroplanes and Rotorcrafts, that operate in non-segregated airspaces **Airspace Class** The TSAA/TSAA+ application is intended to be used in controlled and uncontrolled, (i.e., ICAO airspace class A to G). Maximum benefits are expected to be realized from a safety perspective in airspace where separation is not provided by ATC between all traffic (i.e., class C to G airspace for VFR and class D to G for IFR).

Flight Phases

The TSAA/TSAA+ application is aimed to be used from take-off from the surface until touchdown on landing to alert on any detected airborne conflict. Maximum benefits are expected near airports, and for SA+ when there is a potential of encounters with TCAS II-equipped commercial aviation.

In operations where aircraft routinely fly closer than usual (e.g., formation flying, high density approaches such as fly-ins, fire-fighting operations), excessive nuisance alerts may be generated[2].

Flight Rules and Meteorological Conditions

The TSAA/TSAA+ application will be installed on aircraft operating under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR).

The TSAA/TSAA+ application will be used under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC).

ADS-B Out Equipage

TSAA and TSAA+ can perform their intended function only against intruder aircraft which have ADS-B Out capability.

In ECAC airspace, current ADS-B Out mandate (see [7]) applies to:

- IFR/GAT aircraft with MTOW >5700 kg OR max true airspeed capability >250 knots
- Fixed Wing Transport-Type State aircraft with MTOW >5700 kg OR max true airspeed capability >250 knots

Various studies are ongoing aiming at verifying if mandate on ADS-B out can be extended, and/or under which conditions voluntary equipage of ADS-B Out on other aircraft is possible.

In Europe, the only operational environment where ADS-B OUT equipment can be expected to be installed and operational on most aircraft is Class A airspace, in which only IFR traffic is accepted, and can be reasonably assumed to be constituted by Commercial Air Traffic (i.e. covered by ADS-B Out mandate). In all other airspace classes, traffic with and without ADS-B Out capability can be expected.

TCAS II Equipage

Additional TSAA+ benefits are achievable against aircraft equipped with TCAS II (and in future ACAS X). Current mandate in EU ([6]) requires the following turbine-powered aeroplanes are equipped with ACAS II collision avoidance (logic version 7.1):

- aeroplanes with a maximum certificated take-off mass exceeding 5 700 kg; or
- aeroplanes authorised to carry more than 19 passengers.

There is an exception for State Aircraft. However, the Military Authorities of the ECAC Member States agreed on a voluntary installation program on military transport-type aircraft (MTTA) equivalent to their civilian counterparts by 1 January 2005. Notwithstanding that the military commitment is

[2] TSAA equipment has the capability to acknowledge an active alert and suppress the remainder of the voice annunciation

voluntary, Germany has made ACAS II mandatory within its airspace from 1 January 2005 for all aircraft whether civil or MTTA. **Aircraft Densities** TSAA/TSAA+ applications shall be used in airspaces in which traffic density can range from low to very high. **Airport Characteristics** All categories of Airports are considered for TSAA/TSAA+, including large (intercontinental and international HUBs) and small (regional, local). As a minimum the following SESAR airports categories will be considered, which represent European airports representing 70% of all European flights in 2012, either departed from or arrived at one of these airports: • LUSL Airport: Low Utilisation (<90% utilisation during 1 or 2 peak periods a day), Simple Layout. • LUCL Airport: Low Utilisation (<90% utilisation during 1 or 2 peak periods a day), Complex Layout • HUSL Airport: High Utilisation airports (>90% utilisation during 3 or more peak periods a day), Simple Layout • HUCL Airport: High Utilisation airports (>90% utilisation during 3 or more peak periods a day), Complex Layout

3.2.2 Roles and Responsibilities

Node	Responsibilities
Flight Deck	Performs all the on-board AU operations including flight execution/monitoring according to agreed trajectory, compliance with ATC clearances/instructions, etc. [RELATED ACTORS/ROLES] Flight Crew

Operational interactions per context (NOV-2)		Operating Environment
[Safety Nets] Airborne Collision Avoidance for General Aviation and Rotorcraft - ACAS Xp		**Mixed En-Route/Terminal** High Complexity Low Complexity Medium Complexity Very High Complexity
Node	Node instance	Node instance description
Flight Deck	Flight Deck with TCAS II	In vicinity of the aircraft N°1 (in the same class of airspace) another aircraft N°2 is flying under IFR condition. ATCo provides to this aircraft N°2 ATC service

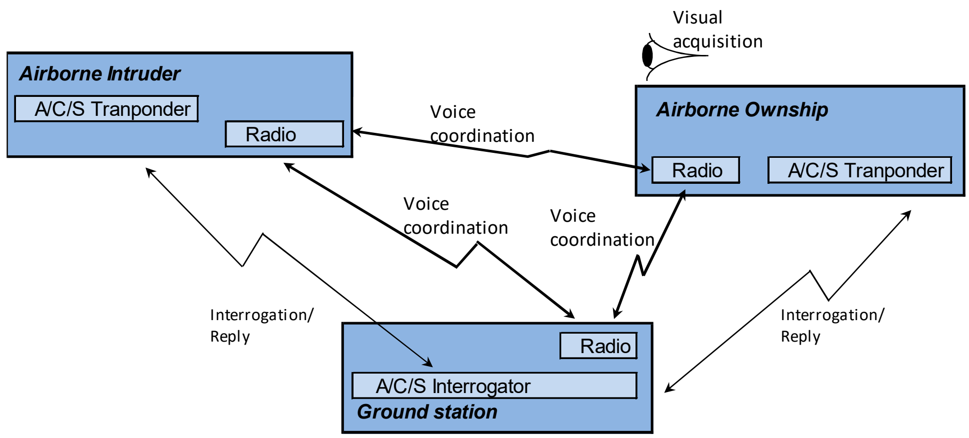
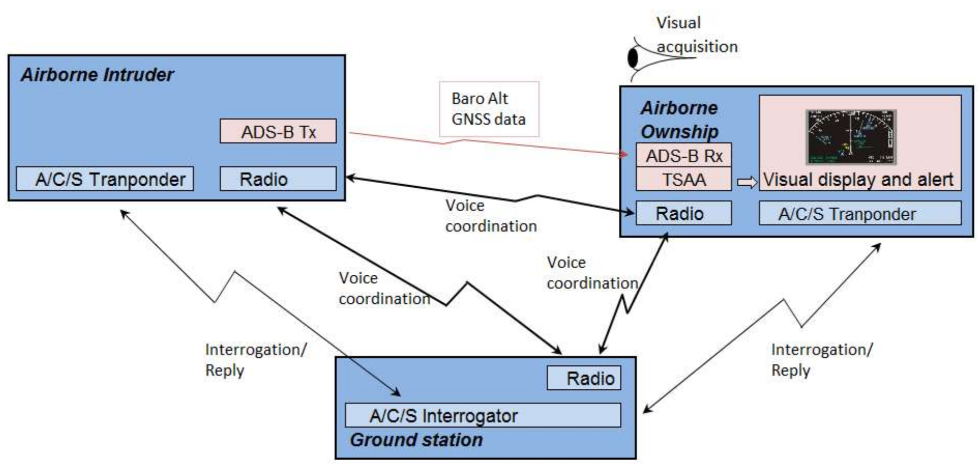
		(separation) from other IFR flights, not from VFR flights. Because aircraft N°1 is flying under VFR condition, ATCo does not provide ATC service (separation) to aircraft N°2 in relation to aircraft N°1 (ANS provide to aircraft N°2 the traffic information about VFR flights and the traffic avoidance advice on request only). Aircraft N°2 is equipped with TCAS II and ADS-B/ OUT
Flight Deck	Flight Deck with TSAA+	Aircraft N°1 which is not equipped with TCAS II is flying under VFR condition in controlled airspace, class D. In accordance with the air space classification, it means that ATC service (separation) is not provided to aircraft N°1 flying under VFR condition (ANS provide to aircraft N°1 the traffic information and the traffic avoidance advice on request only). Aircraft N°1 is equipped with TSAA+ and may or may not be equipped with ADS-B OUT

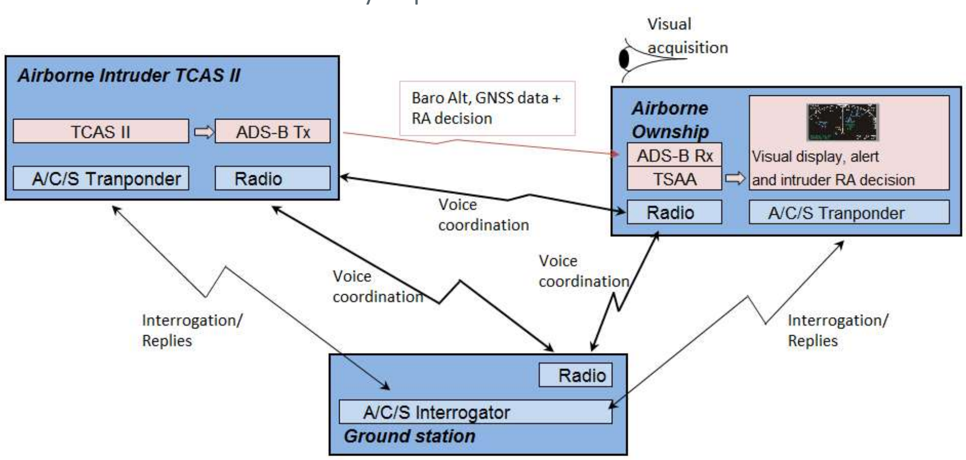
According to the last EATMA meta-model v10.0, the Stakeholders realise the Nodes. In the scope of the solution PJ.11-A4, the **stakeholder** that realise the Flight Deck node is the **Airspace Users**. Specifically it is realised by its following children:

- Civil Business Aviation-Fixed Wing
- Civil Business Aviation-Rotorcraft
- Civil Scheduled Aviation
- Military Fighter
- Military Light Aircraft
- Military Transport
-

3.2.3 Technical Characteristics

Technical constraint	description
Current System overview	The current system overview is based on Interrogator/Transponder exchange, and radio communication.

	Visual acquisition permits to cover the risk of collision avoidance not detected by ground station. In this case, rule of the air detailed in section 3.3 is to apply.  **<u>Current system overview</u>** As indicated in section 3.3, it is important to notice, that some parts of the airspace are not covered by ground station and radio communication. Thus, in the worst case, only visual acquisition is available. As described in section 3.3, visual acquisition is based on human factor and the capability of the pilot to estimate relative position and speed of the intruder.
TSAA System overview	TSAA implementation permits to reduce the human factor risk. As an aid for the Pilot's visual acquisition, TSAA function provides aural warning, visual cue and optionally a proper symbology on an optional Traffic Situation Awareness display. In case of risk of collision detected by TSAA, alert is generated for the pilot.  TSAA system is based on the ADS-B deployment.

	Intruder and more generally, all the aircraft, have to be equipped with an ADS-B transmitter which permits to generate continuously its own GNSS position, speed and cap. ADS-B transmitter has to be in line with DO260B squitter version 2, but for safety reason, ADS-B receiver which detects and decodes these data has to be compatible with DO260/A/B squitter versions 0, 1 and 2 sequentially. After detection and decoding, ADS-B receiver initiates tracks which are transmitted to the TSAA process. TSAA evaluates the risk of collision and transmits track information and potential alert to the visual and audio display. For airborne ownship, it will be necessary to use GNSS and altitude barometric data to determine own aircraft position. GNSS and altitude barometric equipment characteristics have to be defined in order to have a relative position and speed performances necessaries for TSAA. In a first approach, DO229E standard has to be considered for GNNS performances.
TSAA+ System overview	In addition to the TSAA, TSAA+ permits to the pilot to know the manoeuvre planned by the intruder. This concerns only intruder TCAS equipped. In case of collision risk, TCAS II decides a vertical manoeuvre (climb or descent) which is transmitted into a specific squitter (RA decision —Resolution Advisory decision) thanks to the ADS-B transmitter. With TSAA+, ADS-B receiver has to be able to detect this squitter and inform the pilot to the intruder intention. For TCAS II, DO185B version 7.1 of the airborne collision avoidance system (ACAS II) to avoid mid-air collision is currently required. 

3.2.4 Applicable standards and regulations

Standard Name
[1] DO-338, Minimum Aviation System Performance Standards (MASPS) for ADS-B Traffic Surveillance Systems and Applications (ATSSA), June 13, 2012.
[2] DO-242A, Minimum Aviation System Performance Standards for Automatic Dependent Surveillance Broadcast (ADS-B), June 25, 2002
[3] ED-102A / DO-260B, Minimum Operational Performance Standards for 1090 MHz Extended Squitter Automatic Dependent Surveillance – Broadcast (ADS-B) and Traffic Information Services – Broadcast (TIS-B), with Corrigendum 1 included, December 2011.
[4] ED-194A / RTCA DO-317B, “Minimum Operations Performance Standards (MOPS) for Aircraft Surveillance Applications (ASA) System”, 06/2014
[5] ED-232 / RTCA DO-348, “SAFETY, PERFORMANCE AND INTEROPERABILITY REQUIREMENTS DOCUMENT FOR TRAFFIC SITUATION AWARENESS WITH ALERTS (TSAA)”, 06/2014
[6] Commission Regulation (EU) No 1332/2011 of 16 December 2011 laying down common airspace usage requirements and operating procedures for airborne collision avoidance
[7] European Commission Implementing Regulation (EU) No 1207/2011 - Requirements for the performance and the interoperability of surveillance for the SES, and its amendments Regulations (EC) No 1028/2014 and 2017/386 of 6 March 2017.

3.3 Detailed Operating Method

TSAA is intended to reduce the number of mid-air collisions (MAC) and near mid-air collision (NMAC) involving GA a/c assisting the pilot in the “see-and-avoid”, by provision of timely alerts of qualified airborne traffic in the vicinity of ownship, based on ADS-B surveillance and by using alerting logic that is optimized for general aviation flight operations.

TSAA+ capability refers to enhancement of Traffic Situational Awareness with Alerts **(TSAA)** application enhanced to use information about intruder RA (Resolution Advisory), and indicate it to Pilot.

3.3.1 Previous Operating Method

The flight crew’s primary responsibility is to safely fly the aircraft (Aviate, Navigate, and Communicate). As part of the see-and-avoid concept, traffic situation awareness is a major portion of the “Aviate” function. The flight crew develops traffic situation awareness by out-the-window visual scanning, and, when available, cockpit traffic displays and radio communication.

For the purpose of this document it is assumed as previous operating method for GAA/Rotorcraft/State Aeroplanes flight operations, that flight crews build traffic situation awareness over time by integrating available information only from out-the-window observation and radio communications, and that no other cockpit traffic displays and systems are available ([53]).

This is consistent with the fact that for GA/R/StA:

- there is not a mandate on ADS-B Out
- there is not a mandate on ACAS

Depending on the airspace and the flight rules (IFR or VFR), relevant radio communications can include:

- traffic information provided to ownship by a controller,
- transmissions from a controller to other aircraft on a monitored frequency,
- responses from the other aircraft (the "party-line effect"), and
- direct pilot-to-pilot advisories (e.g., traffic pattern reports).

The flight crew must comply with existing ICAO SARPS, for instance Annex 2 - Rules of the Air, Chapter 3 - General Rules, Section 3.6 - Air Traffic Control Service, paragraph 3.6.2 - Adherence to Flight Plan.

Section below provides a description of specific operating method for General Aviation, Rotorcraft and Military aircraft.

3.3.1.1 General Aviation

In general, an aircraft can operate under Visual Flight Rules (VFR), Instrument Flight Rules (IFR) or Special Visual Flight Rules (SVFR):

- **VFR (Visual flight Rules)**: The pilot will navigate with visual markings on the ground and ensure his spacing with another device in a visual way. VFR flight may only be carried out by meteorological conditions VMC (Visual Meteorological Conditions).
- **SVFR (Special Visual Flight Rules):** the definition for SVFR may be different in different countries, depending on the local aviation regulations. The ICAO definition of Special VFR flight is a VFR flight cleared by air traffic control to operate within a control zone in meteorological conditions below VMC
- **IFR (Instrument Flight Rules):** The pilot will navigate without visual markings on the ground, using his instruments. For this purpose, the aircraft must have a IFR certification and the pilot must have the IFR qualification.

Airspace is divided into two main categories, depending on the fact that ATC provides or not any service:

1) Controlled airspace (ICAO airspace classes A/B/C/D/E)
2) Uncontrolled airspace where radio is not mandatory (ICAO airspace classes F/G)

The airspace is large, but it could be congested, especially around aerodromes on weekends. There are several rules and priorities to prevent collisions, which are part of the so-called Rule of the Air.

Due to their maneuvering capacity, some aircraft have priority. The priorities are as follows:

- Powered aircraft must give way to dirigibles, gliders and hot air balloons.
- Airships must give way to gliders and hot air balloons.
- Gliders must give way to hot air balloons.

- The aircraft flying alone must yield the passage to the couplings (towing of gliders ...) and aircraft flying on patrol.

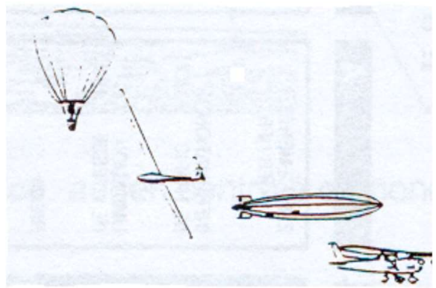


Figure 3: Priority between flying object

The priority of passage is to the aircraft arriving from the right. Spacing > 150 m compared to other aircraft.

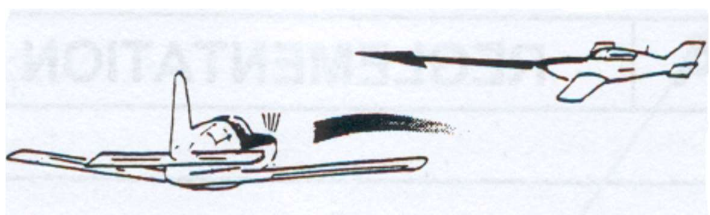


Figure 4: Priority of passage

The fastest aircraft overtakes the slowest aircraft by the right.

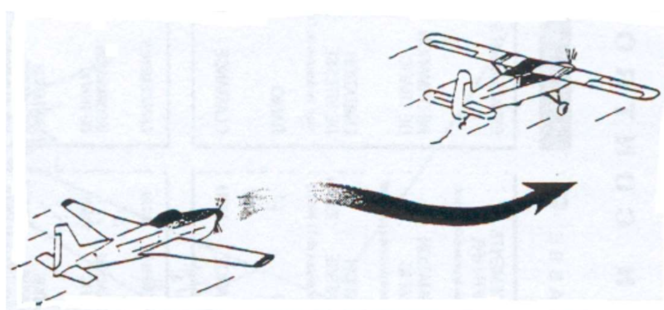


Figure 5: Passing rules

In front approach the two aircraft avoid by the right.

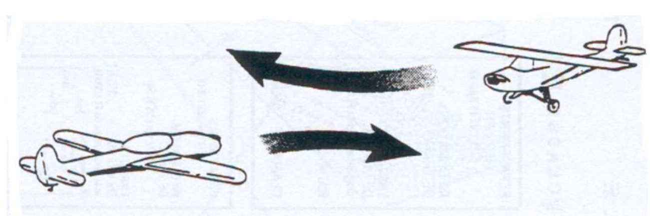


Figure 6: Crossing rules

In the case of simultaneous presentation at landing, the lowest aircraft has priority. Example: aircraft No. 1 has priority over aircraft No. 2 (plus No. 1 is in Final, while the No. 2 is in the last turn). The aircraft No. 3 gives priority to the other two aircraft

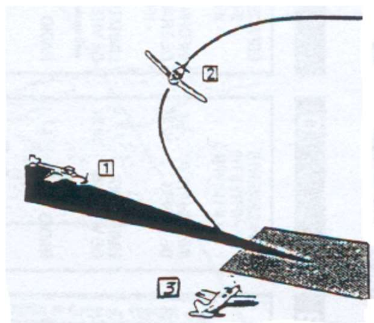


Figure 7: Landing priority

Other Rules

(A) the aircraft with the priority of passage shall retain its course and speed;

(B) when a pilot knows that the maneuverability of another aircraft is being hampered, he transfers the passage to that aircraft;

(C) an aircraft which, under the following rules, is obliged to surrender the passage to another aircraft, shall avoid passing over or under it, or before it, unless do so at a good distance and take into account the wake turbulence

Thus, the current operating method is mainly based on the view and human factor.

Concerning the human factor it is important to see that the vigilance depends on time of day.

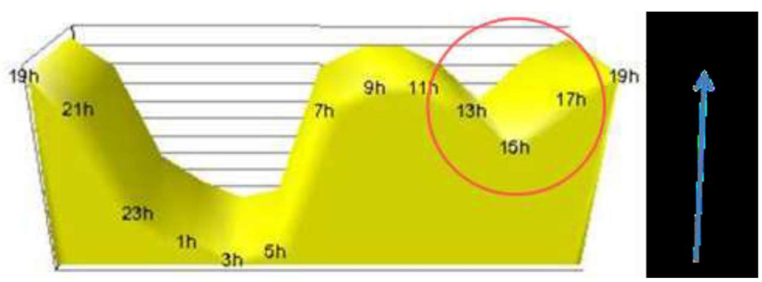


Figure 8: Biorhythm

The performance of the “anti-collision” performance is mainly based on the view of the pilot and its capacity of appreciating the distance between aircraft and the relative speed.

The closing speed must be taken into account in the prevention of collisions. However, this has to be put into perspective for two reasons:

- only the low closing speeds guarantee a near total safety. A study showed that while 97% of collisions could be avoided by application of the "see and avoid" rule for closer 200 kt, this rate fell to 47% for closing speed of 400 kt.

- thus two aircraft complying with the speed limit of 250 kt imposed in VFR rules and flying on strictly opposite conflicting trajectories would have a speed of approximation of 500 kt. The probability that none of the 2 pilots see the other aircraft in time to avoid a collision would be greater than 50%

Figure 9: Example of aircraft visibility, T0 - 4,64 s (distance between aircraft : 1 276 m)

3.3.1.2 Civil Rotorcrafts

Today, civil helicopters are subject to the regulation of General Aviation. The rules of avoidance are the same like for fixed wing although the capacity of maneuvers are clearly not the same.

Anti-collision system is not required, but it is important to note that in some off-shore area like North Sea, some helicopters are equipped with TCASII.

3.3.1.3 State Aeroplanes

Military Aircraft can operate in non-segregated airspace as Operational Air Traffic (OAT) or as General Air Traffic (GAT):

- General Air Traffic (GAT) is applied in Europe to all flights conducted in accordance with the rules and procedures of ICAO. These may include military flights for which ICAO rules satisfy their operational requirements.

- Operational Air Traffic (OAT) is applied in Europe to all flights which do not comply with the provisions stated for general air traffic (GAT) and for which rules and procedures have been specified by appropriate national authorities. Most OAT flights are operated by military agencies.

Although there might be specific rules for State aircraft, in particular for what concerns Military aircraft flying as OAT, there is in general no difference with General Aviation concerning traffic avoidance rules.

Regardless of Military aircraft flying as GAT or OAT, they have flight specificities which are important to take into account:

- Military aircraft may fly at very high speeds, and other airspace users, such as GA and Rotorcrafts pilots, may not consider this properly when deciding their avoidance maneuver, with a non-negligible risk to take wrong decisions;
- Formation flights with military aircraft at a very short distance are a critical case where maneuver decisions of those military aircrafts have to be coherent. GA pilot is not used to this configuration;
- It is important to notice that in formation flights, only the leader has its transponder switched ON;
- Cases of intercepting flights and refueling flights (with tankers) with specific versions of TCAS (e.g. eTCAS, MILCAS) have to be considered.

3.3.2 New SESAR Operating Method

This section is divided into two subsections due to fact that TSAA+ capability is built upon already existing TSAA applications. First subsection describes TSAA operating method and second one addresses the proposed enhancement introduced by TSAA+ and difference with regard to TSAA.

3.3.2.1 TSAA Operating Method

The intended function of the TSAA application is to provide timely alerts of qualified airborne traffic in the vicinity of ownship in order to increase flight crew traffic situation awareness. The TSAA application is intended to reduce the risk of a near mid-air or mid-air collision by aiding in visual acquisition as part of the flight crew's existing see-and-avoid responsibility.

When visual cues are provided on a Traffic Display, the TSAA application builds upon the minimum requirements of the Enhanced Visual Acquisition (EVAcq) application and in some implementations, it could build upon the Basic Airborne Situation Awareness (AIRB) application as described in [4]. EVAcq and AIRB are very similar Airborne Surveillance Applications. While in EVAcq the CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window, in AIRB the CDTI provides traffic information to assist the flight crew in visually acquiring traffic out the window and provide traffic situation awareness beyond visual range[3].

TSAA Traffic Caution Alerts are not directive (i.e., do not provide manoeuvre guidance or commands), and are therefore similar to alerts on TCAS I, TAS, and Traffic Information System (TIS). However, TSAA

[3] on top of the EVAcq requirements, AIRB also needs to provide Traffic ID, Traffic Category (i.e., Emitter Category) and Traffic Ground Speed for display to the flight crew. The EVAcq application is envisaged to only be installed on smaller aircraft, while the AIRB application defines the requirements ASA systems must meet to provide a foundation for additional ASA applications (SURF, VSA, ITP and CAVS).

differs from these legacy systems by utilizing ADS-B surveillance sources and by using alerting logic that is optimized for general aviation flight operations.

The TSAA application is envisioned for use on aircraft without TCAS II or ACAS-X. The application is for use on civil aircraft and rotorcraft. Additionally, public-use aircraft that operate in civilian airspace or military aircraft could potentially utilize this application to reduce the risk of a mid-air collision.

3.3.2.1.1 System Outputs

Nearby Airborne Traffic

Nearby Airborne Traffic is an indication on a Traffic Display that visually differentiates aircraft within a given range and altitude of ownship from other traffic. These indications assist the flight crew in prioritizing activities and are expected to occur for normal traffic situations, and therefore are not advisory-level alerts. The indication of Nearby Airborne Traffic is used to support out-the-window visual acquisition.

Figure 10: An illustrative example of CDTI

Traffic Caution Alerts

The TSAA application provides Traffic Caution Alerts to the flight crew. These alerts are issued when a Target Aircraft is a potential threat and the flight crew needs to visually acquire the Target Aircraft or query Air Traffic Control (ATC). In normal operations, no alerts are issued.

Traffic Caution Alerts provide visual and aural cues to the flight crew. The aural cue consists of the word "Traffic", the bearing of the traffic, its range and relative altitude.

Vertical sense may also be provided when traffic is determined to be climbing or descending. The aural annunciations and visual cues support the out-the-window visual acquisition of the Alerted Traffic.

A Traffic Caution Alert is triggered when the TSAA application detects that a conflict between ownship and any Target Aircraft increases the risk of a near mid-air or mid-air collision above a defined threshold (i.e., a potential threat). This is intended to occur in non-normal traffic situations where most flight crews would benefit from increased traffic situation awareness. Nominally, the TSAA application is expected to provide the flight crew with adequate time to respond to the Traffic Caution Alert. Current traffic alerting systems nominally provide 20 to 40 seconds of time for flight crew response. However, Traffic Caution Alerts may provide less than the nominal amount of time due to sudden manoeuvring of a Target Aircraft or ownship. This value may be refined during the performance analysis.

During active alerts, TSAA provides updated information on Alerted Traffic. Flight crews can obtain this information visually from a Traffic Display (the displayed information is continuously updated), if available. If the Traffic Display is not available, flight crews will be able to obtain updated voice annunciations containing the same information as the Traffic Caution Alert through a manual request function, or as a result of a supplemental auto-update function.

NOTE: When implemented, the auto-update function should trigger when the two aircraft continue to close on each other. It is anticipated that an auto-update would be generated in only a small subset of situations where a Traffic Caution Alert is issued.

NOTE: Whether an update is automatic or manual, it is anticipated that the voice annunciation will be identical to the Traffic Caution Alert in every way (e.g., wording, volume, inflection, and cadence). TSAA alerts are caution alerts since they require immediate flight crew awareness, and, potentially, a subsequent flight crew response. Traffic Caution Alerts are not warning alerts because an immediate flight crew response is not required, only immediate flight crew awareness. Warnings from traffic alerting systems are, by definition, reserved for collision avoidance systems with directive alerts that command a response from the flight crew, such as TCAS II Resolution Advisories (RAs).

NOTE: The TSAA Traffic Caution Alerts helps the flight crew to visually acquire Alerted Traffic, but unlike TCAS II RAs, TSAA Traffic Caution Alerts do not provide resolution guidance to the flight crew. TSAA Traffic Caution Alerts are similar to TCAS I or TAS Traffic Advisories (TAs), which do not provide manoeuvre resolution information.

Some traffic may not have ADS-B quality parameters (e.g., position integrity) or other attributes (e.g., update rate) sufficient to generate Traffic Caution Alerts. The data quality for display of traffic on the Traffic Display is that required by the underlying application (i.e., AIRB or EvAcq).

Flight crews are responsible for understanding that, because ADS-B is a cooperative surveillance system the TSAA application does not guarantee that all traffic will be displayed or alerted upon. Absence of any voice annunciation and/or visual cue does not constitute a conflict-free or target-free environment.

3.3.2.1.2 Operations with the TSAA Application

The flight crew's primary responsibility is to safely fly the aircraft (Aviate, Navigate, and Communicate). As part of the see-and-avoid concept, traffic situation awareness is a major portion of the "Aviate" function. The flight crew develops traffic situation awareness by out-the-window visual scanning, and, when available, cockpit traffic displays and radio communication.

In the event of a Traffic Caution Alert, the presence of an alert condition is conveyed through attention-getting visual cues, voice annunciations, and, if available, Traffic Display symbol change.

NOTE: When the TSAA application is operating on a multifunction display, the flight crew will be able to access the traffic display function.

When an alert condition is detected by the flight crew, the flight crew will search out the window for Alerted Traffic or consult the Traffic Display, if available, for the relative location of the Alerted Traffic.

NOTE: Voice annunciations of Alerted Traffic relative bearing, range, altitude, and optionally vertical sense are provided for caution level alerts which also aid the flight crew to visually acquire the Alerted Traffic.

Nearby Airborne Traffic is available only for those installations that include a Traffic Display. No attention-getting mechanism is required beyond the Traffic Display symbol change for Nearby Airborne Traffic.

As in VFR operations today, if the Nearby Airborne Traffic or Alerted Traffic or any other aircraft is visually identified, the flight crew makes a decision on whether a see-and-avoid manoeuvre is the safest course of action. If it is not necessary, the flight crew continues to fly the aircraft as usual. If a manoeuvre is necessary, the flight crew manoeuvres based on visual acquisition of the Target Aircraft. After the flight crew manoeuvres to avoid the Alerted Traffic, the flight crew returns to the desired flight path and contacts ATC if appropriate.

NOTE: Minor changes in attitude (e.g., lowering the nose in a climb, or raising a wing) are techniques used in visual acquisition of an aircraft and are therefore not considered manoeuvres.

NOTE: When the flight crew utilizes knowledge about a Target Aircraft's prior, current, or expected behaviour, ATC Traffic Advisories, or any other information that is relevant to the current situation, to determine that a manoeuvre is necessary, the manoeuvre is not made solely on the TSAA Traffic Caution Alert or indication (i.e., Nearby Airborne Traffic).

NOTE: The flight crew must comply with existing ICAO SARPS, for instance Annex 2 - Rules of the Air, Chapter 3 - General Rules, Section 3.6 - Air Traffic Control Service, paragraph 3.6.2 - Adherence to Flight Plan.

If the Target Aircraft is not visually acquired, and ATC Traffic Advisories are available and the flight crew would like traffic advisory information, the flight crew may contact ATC.

When information received from ATC validates the information from the Traffic Display or the TSAA voice annunciation, and the flight crew judges that manoeuvring the aircraft under VFR is the safest course of action, then the flight crew may manoeuvre the aircraft based on the ATC Traffic Advisory. If information received from ATC does not validate the information from the Traffic Display or voice annunciation, or the flight crew judges that a manoeuvre is not necessary, then the flight crew proceeds on its desired flight path.

As in existing operations, if ATC services are being provided to the TSAA-equipped aircraft the flight crew should, time permitting, announce to ATC any intentions to manoeuvre before undertaking the manoeuvre.

If a Target Aircraft cannot be visually acquired and ATC Traffic Advisories are available and desired, the flight crew may request ATC instructions.

3.3.2.1.3 TSAA Equipment Classes

There are two classes of TSAA Equipment:

- **Class 1** equipment provides audio alerts through an annunciator panel and a visual attention getting cue such as a lamp located on the instrument panel. TSAA Class 1 equipment does not include a Traffic Display.
- **Class 2** equipment provides audio alerts and a Cockpit Display of Traffic Information (CDTI).

	Class 1	Class 2
Voice Annunciation	Required	Required
Attention-getting Visual cue	Required	As needed[4]
Traffic Display	N/A	Required

Table 5: Classis of TSAA equipment

Fundamental to see-and-avoid is the direct visual acquisition of traffic. The TSAA application supports the out-the-window visual acquisition of traffic through voice annunciations of alerted traffic, visual cues, and additional symbology to supplement the plan-view depiction of traffic on a Traffic Display, when equipped. Visual cues of Nearby Airborne Traffic are provided by the TSAA application when equipped with a Traffic Display.

Two senses must be stimulated for caution alerts per AC 25.1322-1 and Acceptable Means of Compliance (AMC) 25.1322.

To the greatest extent possible, the attention-getting cues should guide the flight crew's attention out the window to the Target Aircraft. Voice annunciations that provide relative position of the Target Aircraft are a key part of the TSAA application and are necessary to guide the flight crew's attention out the window and keep it out the window. Additionally, for Class 2 equipment, the information on the Traffic Display supplements the voice annunciation of the relative position of the Target Aircraft. Other attention-getting mechanisms such as haptic feedback could be used but are outside the scope of this document.

Class 1 TSAA Equipment is intended for aircraft with limited panel space for new displays or vintage aircraft whose owners want the benefits of ADS-B traffic alerting without modifying the instrument panel. Because there is no Traffic Display, the equipment and installation costs for this class are expected to be lower than Class 2 TSAA Equipment.

Class 1 TSAA Equipment provides voice annunciations for Traffic Caution Alerts. The voice annunciations will provide bearing, range, altitude, and optionally, vertical sense of the Alerted Traffic to support the out-the-window visual acquisition of the traffic (e.g., "Traffic, eleven o'clock, three miles, same altitude" or "Traffic, two o'clock, two thousand feet, three hundred feet above, descending"). Additionally, the Class 1 TSAA Equipment will provide a visual cue (e.g., Crew Alerting System message or labelled lamp) to alert the flight crew.

Class 2 TSAA Equipment requires a Traffic Display compliant with the EVAcq or AIRB requirements as defined in ASA System MOPS [4]. The Traffic Display provides additional assistance in locating Target Aircraft beyond that of Class 1 equipment. As in Class 1 equipment, voice annunciations are also provided. Class 2 equipment provides Traffic Caution Alerts and displays Nearby Airborne Traffic.

[4] Based on installation requirements, attention-getting visual cues can be incorporated in the Traffic Display if it is located appropriately

Depending on the installation, the visual attention-getting cues may be presented on a Traffic Display in a Class 2 installation.

Both classes of equipment may employ a method to allow the flight crew to acknowledge an active alert and suppress the remainder of the currently active voice annunciation.

	Class 1	Class 2
Nearby Airborne Traffic	No	Yes
Traffic Caution Alert	Yes	Yes

Table 6: TSAA information by equipment class

3.3.2.1.4 Relationship to Other ADS-B IN Applications

The TSAA application is designed to function independently or with other ADS-B IN Aircraft Surveillance Applications.

AIRB and EVAcq are ADS-B IN applications for airborne traffic situation awareness that display information about ownship and qualified traffic on a Traffic Display. The TSAA application, when installed with a Traffic Display, will augment EVAcq or AIRB with additional symbols. The TSAA application will change the appearance of the symbol for Nearby Airborne Traffic and Alerted Traffic on the Traffic Display.

It is possible to have more than one ADS-B alerting application on the same aircraft but the operating environments may overlap.

3.3.2.1.5 Relationship to other Traffic Alerting systems

The operation and interaction of the TSAA application with any other airborne traffic alerting capability (e.g., TCAS I, TAS) installed on the same aircraft is outside the scope of this document. If TSAA is installed on an aircraft with TCAS I or TAS, the systems should be integrated as part of installation and/or certification. TSAA alerts will be appropriately prioritized with other systems on the flight deck.

Other existing traffic alerting capabilities are described in Appendix D.

3.3.2.2 TSAA+ Operating Method

TSAA+ will, in addition to visual cues and voice annunciations already being provided by TSAA, benefit from availability of information about RAs broadcasted by TCAS-equipped aircraft. In Europe, TSAA+ will only use ADS-B information (no ADS-R nor TIS-B since those are not operational in Europe) to provide flight crew with indications of nearby aircraft and if nearby, TCAS II-equipped aircraft is issuing RAs, then also an information about RA issued on-board of TCAS II-equipped threat.

TSAA+ is therefore expected to support see-and-avoid responsibility of the pilot, and improve interoperability with TCAS II-equipped aircraft. There is no coordination between TSAA+ application and alerting systems on other aircraft, but TSAA+ can be considered as a first step toward responsive coordination, which strategy requires that intended aircraft knows it is the intruder aircraft for the TCAS-equipped aircraft. TSAA+, as a situational awareness application, **will not provide flight crew with manoeuvre guidance or commands**.

Pilot provided with such information, must consider (when deciding for further action to be taken), in addition to information provided by TSAA+, also following:

- Rule of the Air (SERA.3210, ICAO Annex 2, 14 CFR § 91.113);
- Proximity of clouds (for VFR);
- Proximity of terrain or ground obstacles;
- Proximity, to other traffic, etc.…

3.3.2.2.1 System outputs

- Nearby Airborne Traffic (as by TSAA)
- Traffic Caution Alerts (as by TSAA)
- Information about RA issued on board of TCAS II-equipped a/c[5]

3.3.2.2.2 Roles & Responsibilities

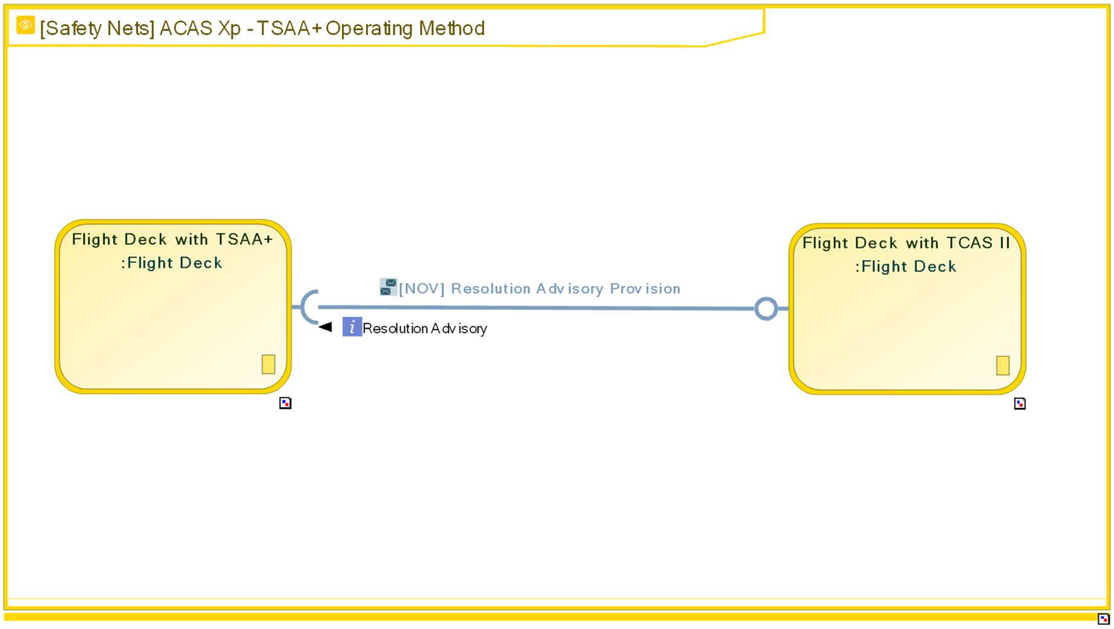
There are no changes in roles and responsibilities for ATC or flight crew. The flight crew would take the same actions as they would under normal see-and-avoid rules when they see a target aircraft. With TSAA+, the flight crew will benefit from increased situational awareness.

In controlled airspace, ATC will still be responsible for providing separation services. Flight crews are still responsible for safe and efficient control and navigation of their individual aircraft in all airspace.

3.3.2.2.3 Exemplar operational scenarios

The exemplar operational scenario involves TSAA+ equipped aircraft and TCAS II-equipped aircraft.

[5] Display and operational aspects of using this information require detailed HP assessment (EXE-04 in V2).



This V1 version of the NAF Operational View 2 (NOV-2) provides the Nodes identified from EATMA that are part of the solution PJ.11-A4.

In the scope of this ACAS Xp solution, it is foreseen that only Flight Deck nodes (either Aircraft or Rotorcraft) will exchange information. All Information Exchanges, as aggregations of the Information Flows identified while describing the Use Cases (NOV-5 views), will be identified and refined during V2 and V3 phases, respectively.

So far, only one Information Exchange carrying a Resolution Advisory (RA) as Information Element has been already identified

With this solution, the nodes will increase their **Mid-Air Collision Avoidance** capability, whose description in EATMA [4] is the following: the avoidance of collision between mobile airborne vehicles.

Such situations can occur:

1. En-route[6] - an exemplar situation depicted at figure shows two en-route TCAS II-equipped aircraft during NMAC, and third – TSAA+ equipped military fighter being aware of the situation and ongoing RA of both threats.

[6] En-route phase is considered when both involved aircraft are not in the phase of approach to/departure from airport.

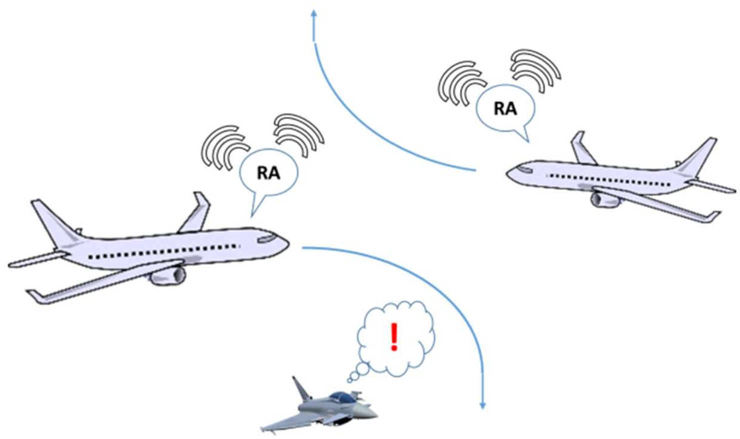


Figure 11: En-route exemplar operational scenario

2. TMA – the most of the use cases are going to be in TMA environment where different types of traffic encounters. Such situations can occur at:

   a. Mixed operations at one airport (airliners, rotorcraft, small aircraft);

   b. Civil/Military mixed operation at one airport;

   c. Large hub airport with smaller regional airports (controlled or uncontrolled) in vicinity where TCAS II-equipped aircraft are approaching hub airport and can encounter with non-TCAS II aircraft approaching smaller, regional airport.

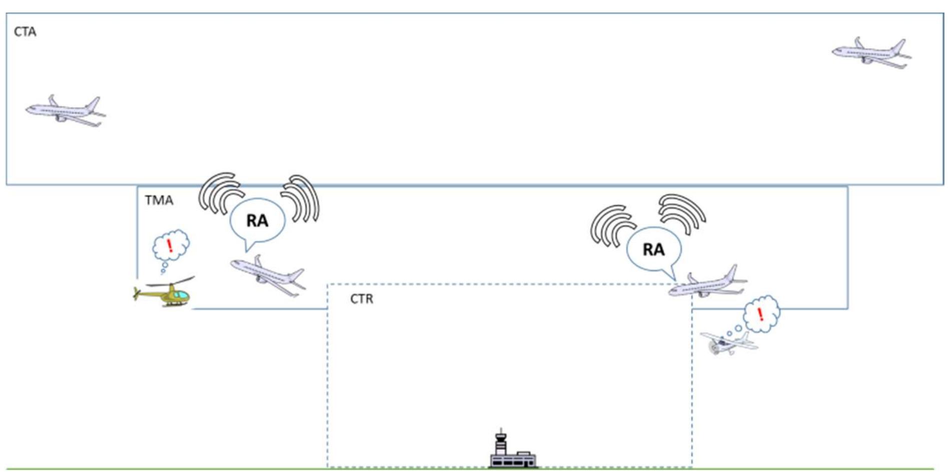


Figure 12: TMA exemplar operational scenario

3.3.2.3 Open Points Related to Cockpit Procedure

TSAA+ application is intended to reduce the risk of NMAC or MAC by aiding in visual acquisition, and to avoid TSAA+ pilot to manoeuvre against RA of TCAS II-equipped aircraft. Initial V1 assumption for the cockpit procedure of GA pilot was NOT to manoeuvre (in the meaning that GA pilot should maintain his course and speed).

Past studies performed by MIT [41] on the **coordination of GA collision avoidance manoeuvre with TCAS Resolution Advisories**, and which should be taken into consideration for the cockpit procedure discussions on SA+ or CA capability, investigated the performance of varying levels of coordination: **full coordination** where the system directly coordinates with TCAS, **responsive coordination** where the system only responds to TCAS (e.g. no own maneuverer is generated on board of GA aircraft, but GA merely responds to TCAS with the goal of avoiding non-coordinated manoeuvring), and **no coordination** at all.

The purpose of the analysis was to help identify the relative benefit on a system's ability to coordinate with TCAS, which can then be used to identify potential technological solutions. There were four different implementations of a responsive coordination tested, assuming that GA aircraft is able to receive Vertical Resolution Advisory Complement (VRC[7]) subfield:

- Level-Off (LO) required pilot to manoeuvre to maintain a vertical speed between +250ft/min and +250ft/min (for both Don't climb and Don't descend).
- Do not descend (DND) / Do not climb (DNC) required pilot to maintain a vertical speed that complies with the VRC code. If the VRC code is Don't climb, then any vertical speed less than or equal to 0ft/min complies with the advisory.
- Descend (D) / Climb (C) required pilot to maintain a vertical speed of at least 500ft/min in the direction that complies with the VRC mode, assuming that aircraft is always able to achieve 500ft/min.
- Maintain vertical speed (MVS) required pilot to maintain the current vertical speed of the aircraft.

The results of the analysis concluded that **Descend/Climb strategy** which requires the most vertical manoeuvring from the GA aircraft, provides the highest level of safety with the lowest probability of NMAC (0.000021 P (NMAC/encounter)).

One of the concerns that study highlighted was the fact that <u>pilot response rate for GA pilots may be so low that equipping with responsive logic might be less safe than not equipping</u>.

Different pilot reactions will be assessed by EXE-05 in the next maturity phase.

[7] Part of TCAS RA broadcast message. The logic on the GA aircraft issued an advisory to the pilot if VRC code is *Don't descend* or *Don't climb*.

3.3.3 Use Cases

Use case N°1

1. Aircraft N°1 which is not equipped with TCAS II is flying under VFR condition in controlled airspace, class D. In accordance with the airspace classification, it means that ATC service (separation) is not provided to aircraft N°1 flying under VFR condition (ANS provide to aircraft N°1 the traffic information and the traffic avoidance advice on request only). **Aircraft N°1 is equipped with TSAA+ and may or may not be equipped with ADS-B OUT**. Aircraft N°1 is equipped with transponder.
2. In vicinity of the aircraft N°1 (in the same class of airspace) another aircraft N°2 is flying under IFR condition. ATC provides to this aircraft N°2 ATC service (separation) from other IFR flights, not from VFR flights. Because aircraft N°1 is flying under VFR condition, ATC does not provide ATC service (separation) to aircraft N°2 in relation to aircraft N°1 (ATC provide to aircraft N°2 the traffic information about VFR flights and the traffic avoidance advice on request only). Aircraft N°2 is equipped with TCAS II and ADS-B/ OUT.
3. Aircraft N°1 receives ADS-B information from aircraft N°2. TSAA+ processes this information and **if traffic equipped with TCAS II is issuing an RA, then the information about RA is passed to the flight crew** and indicated via timely alert. Pilot of aircraft N°1 sees the position of aircraft N°2, tries to reduce risk by reaching visual acquisition and, without maneuvering (i.e. maintain course and speed), **waits for the most appropriate solution from side of aircraft N°2** (RA solution from aircraft equipped with TCAS II).
4. Pilot of aircraft N°2 executes maneuver immediately in accordance with TCAS resolution.

Use case N°2

1. Aircraft N°1 and aircraft N°2 are equipped with TCAS II, both are ADS-B Out equipped and both are flying under IFR conditions. Both aircraft N°1 and N°2 become a threat to each other, and receive an RA again each other.
2. Aircraft N°3, flying in the vicinity, is not equipped with TCAS II is flying under VFR condition in controlled airspace, class D. Aircraft N°3 is equipped with TSAA+ and transponder.
3. Aircraft N°3 receives ADS-B information from both Aircraft N°1 and aircraft N°2. TSAA+ process this information, pass to the flight crew and indicate via timely alert. Pilot of aircraft N°3 sees the position of aircraft N°1 and N°2, tries to reduce risk by reaching visual acquisition and, without maneuvering (i.e. maintain course and speed), **waits for the most appropriate solution from side of aircraft N°1 and N°2** (RA solution from aircraft equipped with TCAS II).
4. Pilots of aircraft N°1 and N°2 executes maneuver immediately in accordance with TCAS resolution.

Use case N°3

1. Aircraft N°1 is not equipped with TCAS II is flying under VFR condition in controlled airspace, class D. Aircraft N°1 is not equipped with TSAA+ either, but is equipped with ADS-B Out.
2. Aircraft N°2 is not equipped with TCAS II is flying under VFR condition in controlled airspace, class D. Aircraft N°2 is equipped with TSAA+, and may or may not be equipped with ADS-B OUT. Aircraft N°2 is equipped with transponder.
3. Aircraft N°3, flying in vicinity, is equipped with TCAS II and ADS-B OUT.

4. Aircraft N°2 receive a Caution Alert against aircraft N°1. Consequently, pilot of aircraft N°2 decides to maneuver, but by doing so, he become a threat for aircraft N°3.

5. Aircraft N°3 issue an RA against aircraft N°2. An RA information is broadcasted and received by aircraft N°2.

6. TSAA+ process this information, pass to the flight crew and indicate via timely alert. Pilot of aircraft N°2 sees the position of aircraft N°3, tries to reduce risk by reaching visual acquisition of both aircraft N°1 and N°3 and, without maneuvering (i.e. maintain course and speed), **waits for the most appropriate solution from side of aircraft N°3** (RA solution from aircraft equipped with TCAS II).

3.3.4 Differences between new and previous Operating Methods

The differences between new and previous operating methods are in following sections captured in two steps. First, the difference between an operating method without any situational awareness system (current operating method) and operating with already standardized TSAA system is considered. Second, the differences between TSAA and TSAA+ are described.

3.3.4.1 Differences between TSAA and previous Operating Methods

From the list of activities available in EATMA, no specific activities were identified as subject to change. However, with the TSAA in place, some activities would extend to other actors (e.g. flight crew) as described in the table below.

Activities (in EATMA) that are impacted by the SESAR Solution	Current Operating Method	New Operating Method (TSAA)
Gain situation awareness on the occurring conflict (a sub-activity of “Monitor and separate traffic in” in all phases of flight activity)	This activity corresponds to tasks of controllers (in EATMA) to provide separation corresponding to the individual phases of flight.	With TSAA the gaining of **situation awareness itself** is extended to flight crew.

Table 7: Difference between TSAA and previous Operating Method

Following paragraphs describe changes in roles and responsibilities introduced by TSAA with respect do different actors and phraseology:

Controller (ATC)

TSAA application does not change the roles or responsibilities for ATC. In controlled airspace, ATC will still be responsible for providing separation services. ATC will also provide traffic information, air traffic advisory, and flight information services.

Flight Crew

The TSAA application does not change the roles or responsibilities for flight crews. Flight crews are still responsible for the safe and efficient control and navigation of their individual aircraft in all airspace. There is no change to techniques currently used by flight crews. The **TSAA application helps the flight**

crew visually scan for relevant traffic by providing Traffic Caution Alerts and Nearby Airborne Traffic indications. The TSAA application can aid the flight crew as they prioritize flight deck activities. In Class 2 installations, the TSAA application may reduce “head down” time used to scan the Traffic Display provided by the EVAcq or AIRB application.

No manoeuvre that would lead to non-compliance (i.e., either a deviation or a non-execution) with an ATC clearance or instruction (e.g., heading, speed, flight level, etc.) or for which visual contact or air-to-air radio communication is a prerequisite can be decided based on the Traffic Caution Alert only. The pilot-in-command is still ultimately responsible for the prevention of collisions.

Impact on phraseology

Procedures associated with the TSAA application do not require phraseology changes and there is no change in the phraseology that is defined in ICAO Doc 4444 [54] or FAA JO7110.65 [55], CAP493 [56].

3.3.4.2 Differences between TSSA+ and previous Operating Methods

The TSAA+ application does not change the operating methods for ATC or flight crew. Their roles and responsibilities remain the same. TSAA+ will however help the flight crew not only to visually scan the relevant traffic based on Traffic Caution Alerts and Nearby Airborne Traffic, but will also enhance situation awareness if ACAS-equipped traffic in vicinity issue a resolution advisory. No manoeuvre that would lead to non-compliance with ATC clearance or instruction, or for which visual contact or air-to-air radio communication is prerequisite can be decided only based on information provided by TSAA+.

From the list of activities available in EATMA, no specific activities were identified as subject to change. However, with the TSAA and TSAA+ in place, some activities would extend to other actors (e.g. flight crew) as described in the table below.

Activities (in EATMA) that are impacted by the SESAR Solution	Current Operating Method	New Operating Method (TSAA)	New Operating Method (TSAA+)
Gain situation awareness on the occurring conflict (a sub-activity of “Monitor and separate traffic in” in all phases of flight activity)	This activity corresponds to tasks of controllers (in EATMA) to provide separation corresponding to the individual phases of flight.	With TSAA the gaining of **situation awareness itself** is extended to flight crew.	Moreover, **with TSAA+ the gaining of situation awareness on the occurring conflict is** extended to flight crew, while ATCO remains responsible for separation of the flight (no change).

Table 8: Difference between TSAA+, TSAA and previous Operating Method

3.4 OSED Assumptions and Requirements

This section summarises the assumptions stemming out from the TSAA OSED but modified for TSAA+, and lays the foundation for the use of TSAA+ application from the Operational and Service perspective relevant for V1 maturity phase. These assumptions are expected to be iteratively refined, and more detailed in next versions of SPR-OSED/INTEROP as the maturity of this solution will increase.

3.4.1 General Assumptions

TSAA+_ASSUMP-OSED.1 The TSAA+ equipment will be installed on and provide alerts to flight crews of airplanes not under ACAS mandate, rotorcraft, and non-ACAS equipped military aircraft.

TSAA+_ASSUMP-OSED.2 The TSAA+ application and TCAS II (or other ACAS systems) will not operate on the same aircraft simultaneously.

TSAA+_ASSUMP-OSED.3 Integration of the TSAA+ application with any other airborne traffic alerting capability will not compromise the intended function of the TSAA+ application or the other alerting capability.

TSAA+_ASSUMP-OSED.4 The TSAA+ application will not change roles or responsibilities for air traffic controllers.

NOTE: It is expected that informational briefings about the introduction of the TSAA application will be available to ATC.

TSAA+_ASSUMP-OSED.5 The TSAA+ application will require no change in existing controller or flight crew phraseology.

3.4.2 Environmental assumptions

TSAA+_ASSUMP-OSED.6 The TSAA+ application will be used in controlled, uncontrolled, and Special Use Airspace.

TSAA+_ASSUMP-OSED.7 The TSAA+ application will be installed on aircraft operating under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR).

TSAA+_ASSUMP-OSED.8 The TSAA+ application will be used under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC).

TSAA+_ASSUMP-OSED.9 Not all aircraft within the environment in which the application is operating will be equipped with ADS-B OUT, transponders for TIS-B broadcast, the TSAA, or TSAA+ application.

TSAA+_ASSUMP-OSED.10 No ground infrastructure changes will be required to support the TSAA+ application.

3.4.3 Receive participant assumptions

TSAA+_ASSUMP-OSED.11 To be consistent with guidance on caution alerts, TSAA+ Traffic Caution Alerts will include voice annunciations and attention-getting visual cues.

TSAA+_ASSUMP-OSED.12 As in existing operations, before any maneuver, the flight crew will perform a visual scan to check if the area they want to maneuver towards is free of traffic, obstacles, and hazardous weather.

TSAA+_ASSUMP-OSED.13 The TSAA+ application will not change roles or responsibilities for flight crews.

NOTE: In the context of this document, the term flight crew refers to one or more pilots. Small general aviation aircraft which will be the primary airframe equipped with TSAA are often operated by a single-pilot flight crew.

TSAA+_ASSUMP-OSED.14 ATC radio communications will be independent from TSAA+ voice annunciations.

NOTE: For example, most general aviation alerting system installations mix audio alerts with ATC communications such that neither is prioritized over the other.

TSAA+_ASSUMP-OSED.15 If TSAA+ installation include display, the location of this Traffic Display is sufficient for TSAA+.

NOTE: As the TSAA+ application is a non-essential traffic situation awareness system, the exact location of the Traffic Display will be determined by the guidelines for the user's application.

TSAA+_ASSUMP-OSED.16 The TSAA+ application will be hosted on ownship with no coordination with other aircraft or with air traffic control. No additional data is required to be transmitted as part of this application.

TSAA+_ASSUMP-OSED.17 The TSAA+ application in European airspace will be based only on a 1090 MHz Extended Squitter (1090ES) ADS-B receiver.

NOTE: Performance of the TSAA+ system would likely be maximized on aircraft with dual [top/bottom] antennae capable of receiving ADS-B messages.

TSAA+_ASSUMP-OSED.18 The TSAA+ application will utilize the same Airborne Surveillance and Separation Assurance Processing (ASSAP) and Traffic Display if other ASA applications are installed in the same aircraft.

3.4.4 Transmit participant assumptions

TSAA+_ASSUMP-OSED.19 TSAA+ targets will be any emitter category except surface vehicles or obstacles as described in DO-338.

3.4.5 Operational requirements

TSAA+_OR.1 The flight crew shall use the TSAA+ application only as a supplement to existing traffic avoidance procedures (e.g., see-and-avoid, radio communications).

TSAA+_OR.2 After a TSAA+ Traffic Caution Alert, the flight crew shall attempt to visually acquire the Alerted Traffic out-the-window using the alert information as appropriate.

TSAA+_ORec.1 After a display of Nearby Airborne Traffic, the flight crew should attempt to visually acquire the Target Aircraft and determine if the Target Aircraft will become a conflict if the aircraft continue on their current flight paths.

NOTE: For the flight crew to have detected Nearby Airborne Traffic, they would have already consulted the Traffic Display. The information provided by the Traffic Display is used to aid in the out-the-window scan for traffic.

TSAA+_OR.3 The flight crew shall not undertake any manoeuvres relative to Alerted Traffic based solely on the TSAA+ Traffic Caution Alert or indication (i.e., Nearby Airborne Traffic).

TSAA+_OR.4 As in existing operations, upon out-the-window visual detection of a Target Aircraft, the flight crew shall take appropriate measures to ensure the safety of the operations.

NOTE: As there is no coordination between the TSAA+ application and alerting systems on other aircraft, the flight crew would take the same actions as they would under normal see-and-avoid rules when they see a Target Aircraft.

TSAA+_ORec.2 If a flight crew determines that a manoeuvre is necessary, the flight crew should use lateral manoeuvres rather than vertical manoeuvres to resolve traffic situations whenever possible.

NOTE: Lateral manoeuvres are preferred for TSAA-equipped aircraft to minimize any potential conflicts with aircraft equipped with TCAS II systems, which provide vertical directed resolution advisories.

4 Safety, Performance and Interoperability Requirements (SPR-INTEROP)

To be completed in V2 SPR-INTEROP/OSED document.

5 References and Applicable Documents

5.1 Applicable Documents

Content Integration

[1] EATMA Guidance Material and Report (2017) - 01 01 00 (1_0)

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System and Service Development

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5.2 Reference Documents

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Appendix A Cost and Benefit Mechanisms

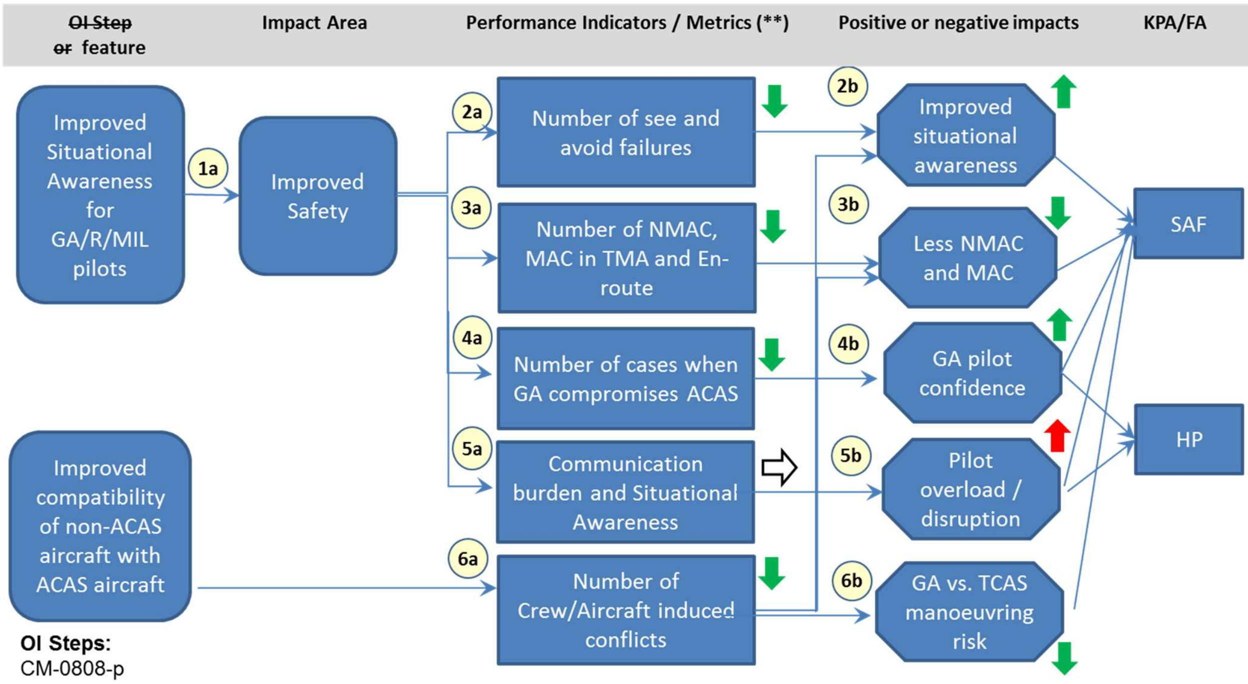
A.1 Stakeholders identification and Expectations

Stakeholder	Involvement	Why it matters to stakeholder
Airspace Users – Pilots: AU -GA AU-Civil Business Aviation – Fixed Wing AU-Civil Business Aviation – Rotorcraft AU-Military Fighter AU-Military Light Aircraft AU-Military Transport	Direct	GA pilots expect to have improved situational awareness by using visual information and being informed about the manoeuvre issued on board of TCAS II equipped aircraft. All pilots expect safety to be maintained or increased (potential reduction of NMAC and MAC). Pilots confidence will be increased if knowing the manoeuvre the intruder is about to take. Pilots expect decreased risk of GA aircraft manoeuvring against TCAS equipped aircraft.
Airspace Users – Scheduled Aviation	Indirect	Airlines expect maintained or increased safety (potential reduction of NMAC).
ANSPs	Indirect	ANSPs expect maintained or increased safety, ideally decreased risk of NMAC/MAC.
Airborne Industry	Indirect	Airborne industry expect to develop useful application improving situational awareness of airspace users in need that will bring revenues (profit). Airborne industry expect to participate in safe integration of GA and rotorcraft operations.
National Governments	Indirect	National governments expect improved overall flight safety through safe GA/Rotorcraft/StA operations integration. They expect reduced risk of NMAC/MAC and thus less time spent on analysis of accidents.
Regulatory Authorities	Indirect	Regulatory authorities expect to have harmonized regulations.

Table 9: Stakeholder's expectations

A.2 Benefits mechanisms

Following diagram describes Benefit & Impact Mechanism for Airspace Users (Pilots), who are the main stakeholder for this solution:



(1a) Improved situational awareness leads to reduced risk of NMAC and MAC thus to improved Safety.
(2a+2b) Safety will be improved is number of see and avoid failures will decrease, e.g. situational awareness will be improved.
(3a+3b) Safety is considered to be increased if number of NMAC and MAC decrease in both TMA and En-Route environments where TSAA+ will operate.
(4a+4) Safety is increased if there is a decrease in number of cases when GA traffic compromises an ACAS-RA on nearby equipped aircraft, intended to resolve a potential collision with it, by not being aware of its existence.
(5a+5b) Communication burden and situation awareness is indicator that needs to be assessed (impact is not yet clear) in relation to safety. It is linked to pilot potential disruption by TSAA+ application, aural alerts may even be too disturbing or useless due to increased noise level in GA aircraft. Paying too much attention to TSAA+ application on board may cause GA pilot missing some non-ADS-B traffic.
(6a+6b,3b, 2b) Improved compatibility of non-ACAS aircraft with ACAS aircraft can be measured by number of crew/aircraft induced conflicts. Goal is the reduction I unnecessary or counter-productive manoeuvers of GA traffic (by altitude or by turns) to ACAS-RA maneuvering aircraft . Reducing the creation of new conflict situations with either the ACAS reacting or other nearby aircraft by increasing situational awareness of ACAS-RA triggered manoeuvres in their vicinity leading to less NMAC and MAC.

Figure 13: BIM for TSAA+ (V1)

A.3 Costs mechanisms

Initial cost assessment was provided in the Initial CBA. In term of costs, there were no costs identified for **ANSPs** or **Airlines.** Indirect costs have been identified for **national governments/administrations and organizations** in terms of expenses for co-financing of R&D work, and decreased costs introduced by less time spent on analysis of accidents (less NMAC & MAC).

Direct costs have been identified for **Airspace Users** and **Airborne Industry**. The latter refers to development costs and investments which lead to final product introduction to the costumer. These costs will not be relevant for CBA analysis, because they will finally become a profit for the airborne industry stakeholder, and input costs are indispensable for the manufacturer in the sense of commercial business.

Airspace User costs are namely the equipment cost, cost of operating/maintaining it, and potential training cost. There will be the same type of costs like for GA/R and Military (e.g. equipage cost, cost of operating and maintaining it, and potential training cost), however, **Military costs are expected to be much higher than cost for GA**. Especially equipage cost since installations (like fighter aircraft) are much more complex and must fulfil much higher MIL-standards. This cost may vary across the different types of aircraft types and even for the same aircraft type operated by different nations.

Appendix B Encounter Categories TSAA

The baseline encounter tracks used for TSAA evaluation is the one contained in ED-232/DO-348 Appendix A-2.

Appendix C Overview of Encounter Models

Solution PJ.11-A4 aims to improve safety of GAA/Rotorcraft/StA operations by addressing three types of mid-air collision risk between:

- GAA/R aircraft and other GAA/R aircraft,
- GAA/R aircraft and an ACAS equipped aircraft due to uncoordinated last moment manoeuvring, and
- State Aeroplanes/Military aircraft flying through a civil airspace and a civil aircraft.

In order to assess the performance and validate systems developed under this solution, there is a need for encounter model representative for GAA/R/StA operations in Europe, which currently does not exist.

Following sections provide an overview of already available encounter models and those which are planned to be developed.

C.1 Existing Encounter Models

Airspace encounter models have evolved significantly over the past 25 years. Beginning with two-dimensional (vertical plane motion) model in the 1980s developed by MITRE using data from 12 radar sites, models were subsequently extended by the ICAO and EUROCONTROL in the 1990s to add simplified three-dimensional motion. [58]

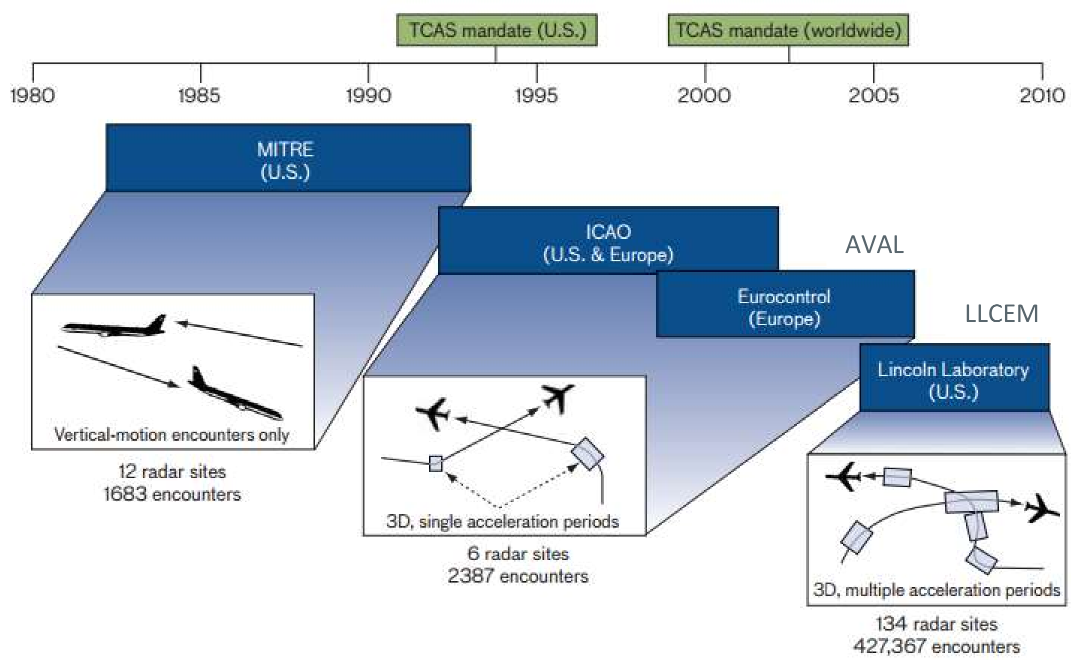


Figure 14: Evolution of encounter models [57]

Two encounter models are primarily used to demonstrate safety benefits of ACAS X under development:

- AVAL – European model based on 2007/2008 radar data
- LLCEM – US airspace model based on 1 year of radar data

In addition, some encounter generators in use but not further described in this appendix are:

- TRAMS – The TCAS RA Monitoring System (TRAMS) records aircraft tracks and RA downlinks from TCAS equipped aircraft receiving RAs in the coverage area of 21 terminal area radars in the US. Encounters created from these recordings are useful in gauging CA operational suitability metrics.
- Stressing Encounters (TCAS Encounter Generator)
- Hazardous Encounters (Safety issue SA01 described in RTCA DO-289)

C.1.1 AVAL safety encounter model

This 'safety encounter model' [58] is a mathematical model of traffic situations involving two aircraft that captures the properties of 'close' encounters captured from radar data. The encounters that matter are those in which two aircraft are on a close encounter course. This is measured by the separation at the 'Closest Point of Approach' (CPA), i.e. the local minimum in the physical distance between two aircraft. It is defined by a horizontal component ('Horizontal Miss Distance - HMD') and a vertical component ('Vertical Miss Distance - VMD'). The safety encounter model addresses encounters with a HMD less than 500 ft at CPA. The VMD can be larger (but with a maximum value) because the model includes a significant proportion of encounters with vertical manoeuvres that increase the aircraft vertical separation at the CPA.

The model defines the statistical distributions and interdependencies of the encounter parameters. These define the characteristics of individual trajectories and their relationship to one another when combined into an encounter that is likely to occur in ATM operations.

The most recent version of the European safety encounter model was developed by the EUROCONTROL AVAL project in 2009. It has been developed based on preceding safety encounter models developed by the EUROCONTROL ASARP and ACASA projects to reflect current operations (e.g. introduction of Very Light Jets in the European airspace).

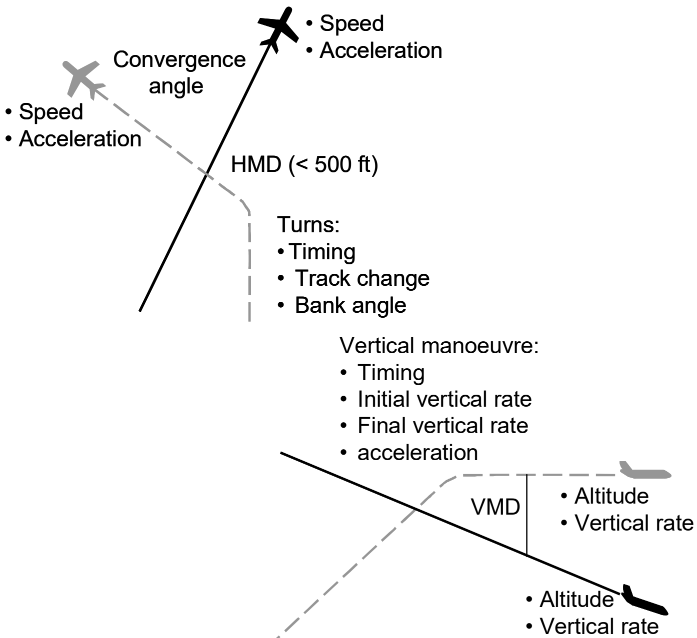


Figure 15: Parameters used to define the AVAL safety encounter model

The probabilities of each of the encounter parameter have been determined by analysing very a large set of encounters extracted from European radar data and counting the number of instances of an encounter with given properties.

The altitude at which each encounter occurs is a dominant feature of the encounter model. The airspace is divided into a number of altitude layers whose boundaries have been chosen to reflect the differing characteristics of the encounters at different altitudes.

Layer	Altitude range
1	100 ft – FL50
2	FL50 – FL135
3	FL135 – FL215
4	FL215 – FL285
5	FL285 – FL415

Table 10: AVAL encounter model airspace layers

About two third of the encounters taken into account by the ‘safety encounter model’, occur in TMA airspace (i.e. below FL135).

The behaviour of an aircraft in an encounter is subject to the limitations of its aerodynamic performance. AVAL has defined the aircraft performance classes based on three parameters:

- the engine type, i.e. piston (P), turboprop (T) or jet (J);
- the Maximum Take-Off Mass (MTOM), including a limit at 5,700 kg to separate light aircraft (L) not subject to the European ACAS mandate from heavier aircraft (H) equipped with TCAS; and

- the maximum cruising speed, i.e. very slow (VS), slow (S), medium (M) and fast (F)

All combinations of these three parameters are not possible. Table 11: AVAL aircraft performance class describes the fourteen performance classes defined in the AVAL safety encounter model (grey cells represent not operationally meaningful cases).

Engine type	MTOM	Maximum cruising speed			
		< 250 kts	250 – 350 kts	350– 450 kts	> 450 kts
Piston	All	P_{VS}	P_S		
Turboprop	< 5,700 kg		TL_S	TL_M	
	> 5,700 kg	TH_{VS}	TH_S	TH_M	
Jet	< 5,700 kg	JL_{VS}	JL_S	JL_M	JL_F
	> 5,700 kg			JH_M	JH_F
Military jet	All				M_F

Table 11: AVAL aircraft performance class

For each of the fourteen performance classes, five performance limits are defined:

- one overall limit:
  - maximum operating altitude;
- four that take different values in different altitude layers:
  - maximum climb rate;
  - maximum descent rate;
  - maximum speed; and
  - minimum speed.

C.1.2 LLCEM safety encounter model

Lincoln Laboratory Conventional Aircraft Encounter Models have been developed by Lincoln Laboratory on a request of FAA to define and generate new encounter models to evaluate TCAS and future collision avoidance for manned and unmanned aircraft in the United States. Models consist of LLCEM (correlated) and LLUEM (uncorrelated) models and were built based on radar data collected over nine months from more than 120 sensors across the continental United States, including data from high density terminal areas as well as en-route regions.

LLCEM It is comprised of two parts. The first is a Bayesian network that models the geometry of two aircraft at point of closest approach, and the second is a dynamic Bayesian network that models how pilot commands transition over time. Both of these models are learned from a large body of radar data over the entire national airspace.

More details on LLCEM model are available in [58].

C.1.3 Differences between European and US airspaces and AVAL and LLCEM models

The major differences between US and European Airspace are:

USA:

- Larger relative flight density
- Larger proportion of General Aviation (GA)
- Higher probability of IFR-VFR encounters (with 500 feet separation)

Europe:

- Higher vertical rates
- Higher probability of en-route conflicts
- Three times as many Adjust Vertical Speed and Level-Off/Level-Off encounters

These differences require independent representative models of the airspaces.

The main differences between European and US models are listed in the table below.

AVAL (Europe)	LLCEM (USA)
Support for Aircraft Classes	No support for Aircraft Classes
Relevant effects of airborne safety nets removed	Relevant effects of airborne safety nets not removed
Significantly fewer NMACs in lower altitude layers	Significantly more NMACs in lower altitude layers
Older technology	Newer technology

Table 12: Differences between AVAL and LLCEM models

C.2 European Encounter Models Under Development

With the development of ACAS Xa, the need representative European model for close encounters was introduced. This need is addressed within EUROCONTROL project CAFÉ which goal is to set up a European validation platform for collision avoidance in SESAR2020 from 2018. The project priority is to establish a representative model for close encounters for European airspace to be used for ACAS Xa.

The approach taken is as described on the figure below and encounter model baseline is scheduled to be available by Q3/2017.

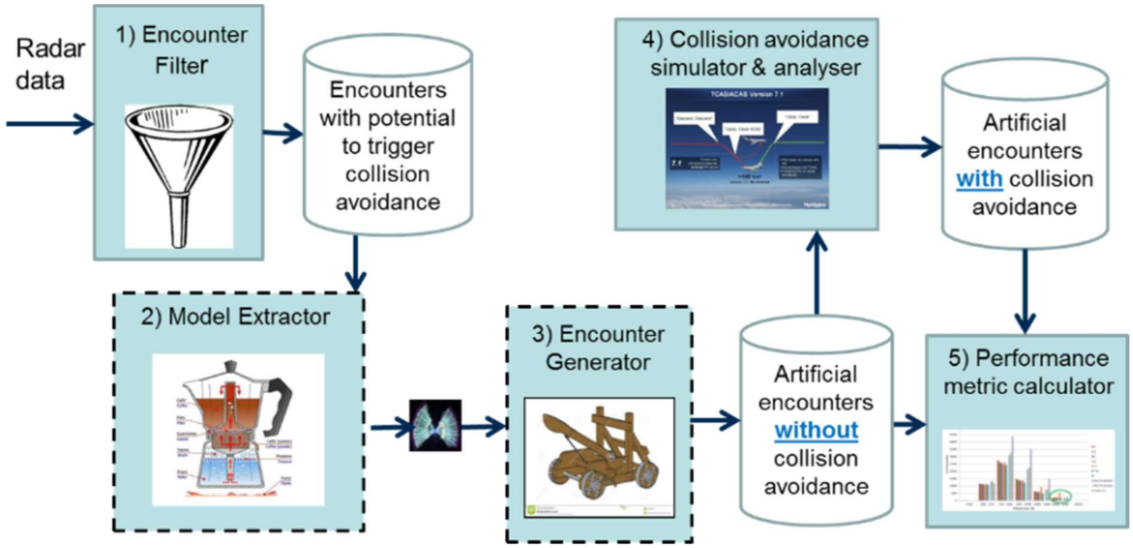


Figure 16: CAFE encounter modelling process

This encounter model is being built based on 1 recent year of radar data collection from six ANSPs in core Europe and includes major and complex TMAs.

With the introduction of ACAS Xu activities under SESAR2020 (PJ.1-A2) and consequently with PJ.11-A4 solution, needs for additional models reflecting RPAS and GA operations was expressed. CAFÉ project was therefore officially extended for to RPAS/DAA objectives aiming to establish a safety performance assessment framework based on encounter modelling capable of coping with RPAS. The specifications are under intensive discussion and definition with expected delivery of first RPAS encounter model in Q2-Q3/2018.

C.2.1 Encounter models for PJ.11-A4

Encounter model representative of European GAA/R/StA operations is a key element for PJ.11-A4 execution. The need identified at the beginning of solution execution was communicated to EUROCONTROL with the request to provide such model for solution validation purposes. With ACAS Xa and ACAS Xu having priority, EUROCONTROL agreed to invest additional effort and support validation activities of TSAA+ and ACAS Xp in the upcoming years.

For the V1 validation purposes of TSAA+, EUROCONTROL offered to provide set of flittered set of encounters involving one equipped and one unequipped aircraft by August 2017. Full GA encounter model would be available after the delivery of Xa and Xu models (e.g. Q3/2018) to support V2 validations of TSAA+ and V1 validation of ACAS Xp.

Following figure depicts different encounters and their applicability for different applications.

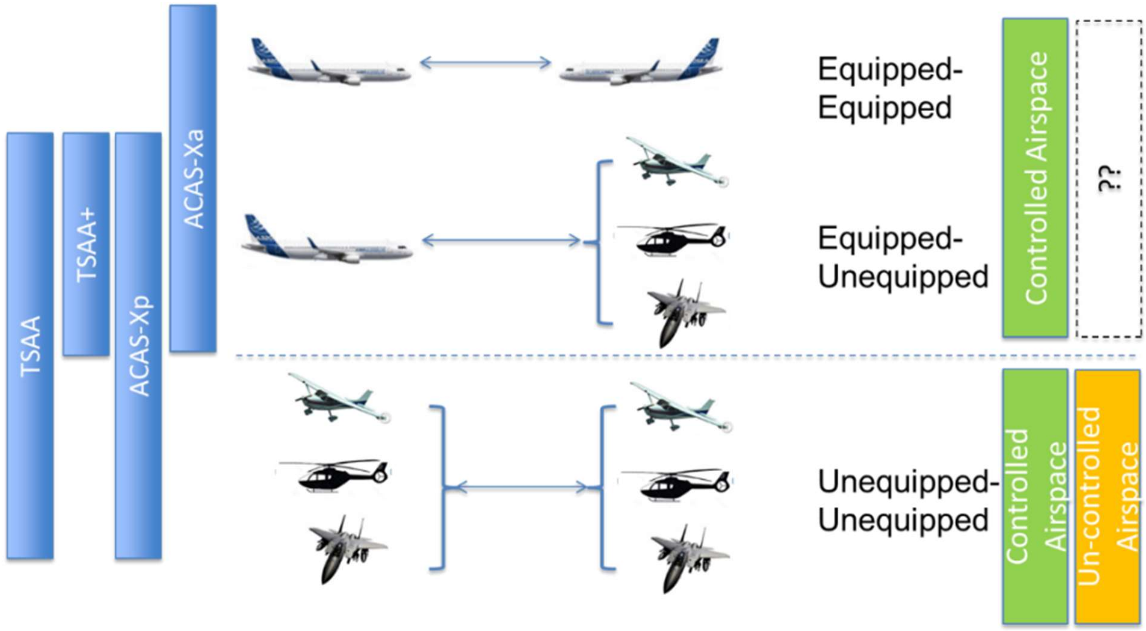


Figure 17: Encounters overview and their applicability for PJ.11-A4

Appendix D Other alerting applications

There are currently other airborne traffic alerting systems available. Select systems are described below and compared in Table 13.

The most common collision detection and avoidance system is TCAS II, as defined in FAA TSO-C119c, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS II with Optional Hybrid Surveillance and EUROCAE ED-143B / RTCA DO-185B, Minimum Operational Performance Standards for Traffic Alert and Collision Avoidance System II. TCAS II is based on Mode-A, -C, and -S transponder interrogations and replies. TCAS II provides situation awareness to flight crews by displaying surrounding traffic. TCAS II has two levels of alerts: Traffic Advisories (which enhance situation awareness) and Resolution Advisories (which provide collision avoidance manoeuvre guidance that is coordinated among the aircraft, when the aircraft involved are equipped with TCAS II systems). Additionally, TCAS II systems provide a symbol change for Proximate Advisories, when targets are within 6 nm laterally and 1200 ft vertically.

TCAS I, defined in FAA TSO-C118, Traffic Alert and Collision Avoidance System (TCAS) Airborne Equipment, TCAS I and RTCA DO-197 works similarly to TCAS II but does not utilize Resolution Advisories or Mode-S datalink for coordination between units. TCAS I provide a single level of alert, a Traffic Advisory (which enhances situation awareness), and there is a limitation on manoeuvring based solely on the Traffic Advisory.

Traffic Advisory System (TAS – FAA TSO-C147) is another traffic alerting system that interrogates nearby transponders like a TCAS I system and enhances situation awareness. TAS systems can also be installed without a plan view display of traffic, instead relying on aural alerts and a “TRAFFIC” annunciation viewable by the flight crew.

Newer versions of TAS systems on the market go beyond the minimum requirements and offer aural position alerting. TAS display symbol may be implemented as TCAS I symbol.

Traffic Information System (TIS), is a traffic awareness system in use in US that utilizes Mode-S radars, which uplink to Mode-S transponders information on nearby transponder-equipped aircraft. However, the update rate of TIS is limited by the rate at which the radar rotates. TIS systems can provide a single type of traffic alert calculated by the ground system in addition to the standard traffic icon.

	TIS	TAS	TCAS I	TCAS II	TSAA
Aural Alerts	Yes	Yes	Yes	Yes	Yes
Visual Alerts	Yes	Yes	Yes	Yes	Yes
Plan view display	Optional (Plan view or textual required)	Yes (Class A) Optional (Class B)	Optional (Plan view or textual required)	Yes	Yes (Class 2) No (Class 1)
Traffic Directionality Resolution on Plan view	45° increments	No	No	No	<5° increments (Class 2) NA (Class 1)
Avoidance guidance	No	No	No	Yes	No
Max Detection range	7nm +3500ft/ -3000ft	12-21nm Typically +/-10000ft	12-40nm Typically +/-10000ft	40nm Typically +/-10000ft	5 nm +/- 2500 ft Airport 10 nm +/- 4500 ft En route
Expected Detection Range	7nm +3500ft/- 3000ft	4-5nm +/-2700ft	4-5nm +/-2700ft	14nm +/-2700ft	3 nm +/- 1500 ft Airport 6 nm +/- 2400 ft En route
Time to Closest Approach for Alert	34 sec	15-30 sec (TA)	15-30 sec (TA)	15-35 sec (RA) 20-48 sec (TA)	25 sec Airport 28 sec En route
Proximate/nearby traffic	6nm +/-1200ft	6nm +/-1200ft	6nm +/-1200ft	6nm +/-1200ft	6nm +/-1200ft
Coverage	ASR-7,8,9 radar coverage	All transponder equipped aircraft	All transponder equipped aircraft	All transponder equipped aircraft	All for ADS-B, TIS-B within SSR coverage and ADS-B Service Volume (SV), ADS-R in ADS-B SVs

Table 13: Comparison of selected airborne traffic alerting systems

NOTE: “Maximum Detection Range” was selected from the maximum range TSAA can alert based on a 60-second look ahead time, and maximum closure rate; this is the value for high altitude en route.

NOTE: “Time to Closest Approach for Alert” values are based on 60% of the maximum range used by the sample algorithm; this is the value for high altitude en routes.

NOTE: These numbers were chosen based on measured data. For en route the average of low and high en route was used.

Appendix E Mapping of ED-232/DO-348 TSAA OSED

This appendix provides traceability of ED-232/DO-348 TSAA OSED with this document.

Initial OSED Section	DO-348 / ED-232 Annex A section	Notes
3.3.2.1.1 System OutputsSystem Outputs	A.3.1 System Outputs	
3.3.2.1.2 Operations with the TSAA Application	A.3.3 Operations with the TSAA application	
3.3.2.1.3 TSAA Equipment Classes	A.3.2 TSAA Equipment Classes	
3.3.2.1.4 Relationship to Other ADS-B IN Applications	A.3.4 Relationship to Other ADS-B IN Applications	
Appendix B	Appendix A-2 Encounter Categories	
Appendix D	Appendix A-1 Other alerting applications	

TSAA+ OSED	TSAA OSED (ED-232/DO-347)	Notes
TSAA+ General Assumptions		
TSAA+_ASSUMP-OSED.1 The TSAA+ equipment will be installed on and provide alerts to flight crews of airplanes not under ACAS mandate, rotorcraft, and non-ACAS equipped military aircraft.	**ASSUMP-OSED.1**	
TSAA+_ASSUMP-OSED.2 The TSAA+ application and TCAS II (or other ACAS systems) will not operate on the same aircraft simultaneously.	**ASSUMP-OSED.2**	
TSAA+_ASSUMP-OSED.3 Integration of the TSAA+ application with any other airborne traffic alerting capability will not compromise the intended function of the TSAA+ application or the other alerting capability.	**ASSUMP-OSED.3**	
TSAA+_ASSUMP-OSED.4 The TSAA+ application will not change roles or responsibilities for air traffic controllers.	**ASSUMP-OSED.13**	
TSAA+_ASSUMP-OSED.5 The TSAA+ application will require no change in existing controller or flight crew phraseology.	**ASSUMP-OSED.15**	

TSAA+ Environmental assumptions		
TSAA+_ASSUMP-OSED.6 The TSAA+ application will be used in controlled, uncontrolled, and Special Use Airspace.	**ASSUMP-OSED.16**	
TSAA+_ASSUMP-OSED.7 The TSAA+ application will be installed on aircraft operating under Instrument Flight Rules (IFR) and Visual Flight Rules (VFR).	**ASSUMP-OSED.17**	
TSAA+_ASSUMP-OSED.8 The TSAA+ application will be used under both Instrument Meteorological Conditions (IMC) and Visual Meteorological Conditions (VMC).	**ASSUMP-OSED.18**	
TSAA+_ASSUMP-OSED.9 Not all aircraft within the environment in which the application is operating will be equipped with ADS-B OUT, transponders for TIS-B broadcast, the TSAA, or TSAA+ application.	**ASSUMP-OSED.19**	
TSAA+_ASSUMP-OSED.10 No ground infrastructure changes will be required to support the TSAA+ application.	**ASSUMP-OSED.20**	
TSAA+ Receive participant assumptions		
TSAA+_ASSUMP-OSED.11 To be consistent with guidance on caution alerts, TSAA+ Traffic Caution Alerts will include voice annunciations and attention-getting visual cues.	**ASSUMP-OSED.5**	
TSAA+_ASSUMP-OSED.12 As in existing operations, before any maneuver, the flight crew will perform a visual scan to check if the area they want to maneuver towards is free of traffic, obstacles, and hazardous weather.	**ASSUMP-OSED.10**	
TSAA+_ASSUMP-OSED.13 The TSAA+ application will not change roles or responsibilities for flight crews.	**ASSUMP-OSED.14**	
TSAA+_ASSUMP-OSED.14 ATC radio communications will be independent from TSAA+ voice annunciations.	**ASSUMP-OSED.6**	
TSAA+_ASSUMP-OSED.15 If TSAA+ installation include display, the location of this Traffic Display is sufficient for TSAA+.	**ASSUMP-OSED.7**	
TSAA+_ASSUMP-OSED.16 The TSAA+ application will be hosted on ownship with no coordination with other aircraft or with air traffic control. No additional data is required to be transmitted as part of this application.	**ASSUMP-OSED.8**	
TSAA+_ASSUMP-OSED.17 The TSAA+ application in European airspace will be based only on a 1090 MHz Extended Squitter (1090ES) ADS-B receiver.	**ASSUMP-OSED.9**	

TSAA+_ASSUMP-OSED.18 The TSAA+ application will utilize the same Airborne Surveillance and Separation Assurance Processing (ASSAP) and Traffic Display if other ASA applications are installed in the same aircraft.	**ASSUMP-OSED.11**	
TSAA+ Transmit participant assumptions		
TSAA+_ASSUMP-OSED.19 TSAA+ targets will be any emitter category except surface vehicles or obstacles as described in DO-338.	**ASSUMP-OSED.21**	
TSAA+ Operational requirements/Recommendations		
TSAA+_OR.1 The flight crew shall use the TSAA+ application only as a supplement to existing traffic avoidance procedures (e.g., see-and-avoid, radio communications).	**OR.1**	
TSAA+_OR.2 After a TSAA+ Traffic Caution Alert, the flight crew shall attempt to visually acquire the Alerted Traffic out-the-window using the alert information as appropriate.	**OR.2**	
TSAA+_ORec.1 After a display of Nearby Airborne Traffic, the flight crew should attempt to visually acquire the Target Aircraft and determine if the Target Aircraft will become a conflict if the aircraft continue on their current flight paths.	**Operational Recommendation.1**	
TSAA+_OR.3 The flight crew shall not undertake any maneuvers relative to Alerted Traffic based solely on the TSAA+ Traffic Caution Alert or indication (i.e., Nearby Airborne Traffic).	**OR.3**	
TSAA+_OR.4 As in existing operations, upon out-the-window visual detection of a Target Aircraft, the flight crew shall take appropriate measures to ensure the safety of the operations.	**OR.4**	
TSAA+_ORec.2 If a flight crew determines that a maneuver is necessary, the flight crew should use lateral maneuvers rather than vertical maneuvers to resolve traffic situations whenever possible.	**Operational Recommendation.2**	