SESAR 2020 TS IRS for ACAS Xa

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CAPITO

CAPITO

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Abstract

The purpose of this document is to summarize an up-to-date status of ACAS X surveillance requirements, definitions, and assumptions, together with a list of any identified open points and gaps. This version is the final version of TS and is based on Minimum Operational Performance Standard for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo), DO-385 and SESAR1 ACAS X technical specifications. The update of document was performed based on the most recent fast-time simulations of Run15.3 of ACAS Xa system, done under PJ.11-A1. For the analysis, the mix of real traffic data collected during various flight tests in European and US airspace was used.

Since ACAS Xa technical specifications are well documented in recently published ACAS Xa/Xo MOPS, this document will mostly serve for proper definition and setting of the ACAS Xa into SESAR European ATM Architecture.

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1 Executive summary

The Federal Aviation Administration (FAA) Collision Avoidance Program Office was developing an advanced Airborne Collision Avoidance System (ACAS), called ACAS X, since 2008 to support the needs of future air traffic environment. Comparing to the existing TCAS II, ACAS X introduces essential changes in the functional (software) architecture, surveillance functions and the collision avoidance logic.

The focus of ACAS Xa development from SESAR perspective was in two streams:

- Technical development of an ACAS Xa implementation where the evolution is captured in terms of releases (so-called "Runs") of the experimental library and the Algorithm Design Description (ADD) document. This document refers to the Run 15.3, which was implemented into experimental platform (Honeywell CASCARA platform) and used for SESAR2020 PJ11.A1 validation.

- Standardization activities (RTCA SC-147 / EUROCAE WG-75) focused on the Minimum Operational Performance Standards (MOPS) development, which was finalized in September 2018 by publication of RTCA DO-385/EUROCAE-256. The baseline for ACAS Xa/Xo MOPS are the existing two standards for TCAS II (DO-185B) and Extended Hybrid Surveillance (DO-300A).

The purpose of this document is to summarize an up-to-date status of ACAS Xa surveillance requirements, definitions, and assumptions, together with a list of any identified open points and gaps. This version is the final version of TS and is based on ACAS Xa/Xo MOPS and SESAR1 ACAS X technical specification (for ACAS Xa Run14). The update of document was performed based on the most recent fast-time simulations of Run15.3 of ACAS Xa system, done under PJ.11-A1. For the analysis, the mix of real traffic data collected during various flight tests in European and US airspace was used.

Since ACAS Xa technical specifications are well documented in recently published DO-385/ED-256 ACAS Xa/Xo MOPS (Errata / Change 1 is expected soon in 2019), and the intention of this document is not to duplicate the MOPS content, this document will mostly serve for proper definition and setting of the ACAS Xa into SESAR European ATM Architecture.

Run 15 ADD delivery (in comparison with Run14 – previously published TS) introduced especially assignment of accuracy associated with NACp = 7 to nominally higher (>7) navigation accuracy position categories to inhibit over-self-confidence of ADS-B tracker, ADS-B tracker modification to support tracking in polar regions, indication consequently inhibiting all TA when ownship "operating on surface", or display of vertical arrow (vertical tracker output) adjustment to prohibit its frequent fluctuation.

In terms of Technical Specifications, this update introduces more significant changes primarily in the structure of document, based on refined high level functional structure. Two new requirements were added, together with appendix mapping STM-related requirements from draft MOPS to requirements defined in this document.

2 Introduction

The Federal Aviation Administration (FAA) Collision Avoidance Program Office was developing an advanced Airborne Collision Avoidance System (ACAS), called ACAS X, since 2008 to support the needs of future air traffic environment. Comparing to the existing TCAS II, ACAS X introduces essential changes in the functional (software) architecture, surveillance functions and the collision avoidance logic.

Introduction of ACAS X is expected to bring important benefits including:

- Reduction of 'unnecessary' (nuisance) advisories by 50% (specifically for ACAS Xa);
- Improved adaptability to future operational concepts (specifically for ACAS Xa);
- Safety improvement by 20% (specifically for ACAS Xa);
- Adaptability of collision avoidance system to various classes of aircraft. Currently four classes of ACAS X are envisioned:
  - ACAS Xa (active) targeting the same classes of aircraft like the current TCAS II. In addition, there is an extra capability ACAS Xo, which is standardized with ACAS Xa and is intended for specific operations that may interfere with the nominal collision avoidance logic, such as closely spaced parallel runway approach;
  - ACAS Xr targeting Rotor Craft[1];
  - ACAS Xu for Unmanned Aircraft Systems; and
  - ACAS sXu focusing on Small Unmanned Aircraft.
- Functional decoupling of the collision avoidance logic from the surveillance;
- Flexibility with respect to use of different surveillance sensors.

Within SESAR2020, the ACAS Xa activities are covered by CAPITO project, solution PJ.11-A1.

2.1 Purpose of the document

The purpose of this document is to summarize an up-to-date status of ACAS X surveillance requirements, definitions, and assumptions, together with a list of any identified open points and gaps. This version is the final version of TS and is based on ACAS X MOPS ([33], [34]) and technical specifications delivered within SESAR 9.47 project, as deliverable D29 (for ACAS Xa Run14, [36]). The update of document was performed based on the most recent fast-time simulations of Run15.3 of ACAS Xa system, done under PJ.11-A1. For the analysis, the mix of real traffic data collected during various flight tests in European and US airspace was used.

Since ACAS Xa technical specifications are well documented in recently published ACAS Xa/Xo MOPS, and the intention of this document is not to duplicate any of already existing requirements within

[1] ACAS Xp (passive) targeting General Aviation was mentioned in the predecessors of this document. Development of this version was not started in fact. Instead of this FAA, RTCA, Massachusetts Institute of Technology and other main contributors are currently focusing on ACAS Xr.

MOPS content, this document will mostly serve for proper definition and setting of the ACAS Xa into SESAR European ATM Architecture.

2.2 Scope

This is the TS-IRS document for solution PJ.11-A1 (ACAS Xa/Xo) for V3 phase.

This TS covers functional and interface requirements, with a strong focus on STM, which was validated within PJ.11-A1 EXE-01 (see [39]). ACAS Xo is out of scope of this document. Above all, there is the solution PJ.11-A3 which is particularly focused on ACAS Xo. It should be noted that there was not identified any use case in Europe for ACAS Xo so far.

2.3 Intended readership

The intended audience for this document are members of PJ.11-A1 solution (EUROCONTROL, DSNA and Airbus) and PJ.11 members in general. At a higher programme level, the Content Integration project (PJ.19) who is responsible for coordination and integration of solutions, as well as development of validation strategy with appropriate validation targets.

2.4 Background

Three previous versions of technical specifications were delivered within SESAR 9.47 project, as deliverables D19 [37], D24 [38], and D29 [36], with focus on surveillance functions (STM). The update of document was performed based on analysis of mix of real traffic data collected during various flight tests in European and US airspace (Extended Hybrid Surveillance /EHS/ flight test data from core European airspace – 2016, EHS flight test data from Phoenix / through European Union / to Hanoi and back – 2016, FAA ACAS Xa Flight test data from Boston area – 2015, and Roof Top data recording in Toulouse – 2016). Except this final version of V3 technical specifications there was no TS document delivered within SESAR 2020 PJ.11 up to now.

2.5 Structure of the document

This document is organized in the following way:

- SESAR solution impact on architecture is described in Section 3 (based on EATMA).
- Functional analysis of the Surveillance & Tracking Module is provided in Section 4.1 (based on EATMA).
- Functional requirements associated with the current design of the Surveillance & Tracking Module are described in Sections 4.2.
- Interfaces of the Surveillance & Tracking Module are described in Appendix A.
- Main data structures of the Surveillance & Tracking Module are described in Appendix B.

2.6 Glossary of terms

Term	Definition	Source of the definition
Implemented functions/features	When this term is used within this document, it refers to functions implemented in Julia[2] within the FAA ACAS X program and described in the corresponding ADD document.	RTCA SC-147
Active surveillance	Surveillance capability where the tracking data about an intruder are obtained through interrogation of its transponder and subsequent analysis of transmission characteristics (delay, incoming direction) of its reply.	RTCA SC-147
Passive surveillance	A type of surveillance including passive tracking, where the tracking data about the target are obtained through ADS-B reports.	RTCA SC-147
Track file	The data structure that contains all of the relevant information on a single target aircraft necessary for estimating the state of the target or to create an STM report. It includes the state estimate, any flags or timestamps.	RTCA SC-147
Coordination	The process of ensuring that two aircraft take complementary (non-conflicting) avoidance manoeuvres when there is an imminent risk of collision between those two aircraft.	RTCA SC-147

Table 1: Glossary

2.7 Acronyms and Terminology

Term	Definition
A/C (a/c)	Aircraft
ACAS	Airborne Collision Avoidance System
ACAS Xa	Airborne Collision Avoidance System X – active surveillance (a member of the ACAS X family that is designed to replace TCAS as seamlessly as possible)
ACAS Xo	Airborne Collision Avoidance System X – operations (a special mode that can be added to ACAS Xa, allowing adapted RAs regarding a crew-designated aircraft)

[2] The programming language created intentionally for ACAS X development.

ADD	Architecture Definition Document
ADS-B	Automatic Dependant Surveillance - Broadcast
ADS-R	Automatic Dependent Surveillance – Re-broadcast
AGL	Above Ground Level
ASA	Aircraft Surveillance Applications
ATM	Air Traffic Management
ATSAW	Airborne Traffic Situation Awareness
CAS	Collision Avoidance System
CASCARA	Collision Avoidance Simulation Components And Runtime Analysis (Honeywell simulation platform)
CC	Capability Configuration
CDTI	Cockpit Display of Traffic Information
ConOps	Concept of Operations
CPA	Closest Point of Approach
CR	Change Request
CSPO	Closely Spaced Parallel Operations
DF	Down Link Format
DF0	DF of Short Air surveillance (ACAS), Mode S transponder reply
DF11	All-Call Reply /Acquisition Squitter
DF16	DF of Long Air-Air Surveillance (ACAS), Mode S transponder reply
DF17	DF of ADS-B Messages from Mode S transponder
DF18	DF of ADS-R messages, TIS-B[3] messages, ADS-B messages from transmitting devices that are not Mode S transponder
DF19	DF of ADS-B messages for Military applications[4]
DSNA	Direction des Services de la Navigation Aérienne (the Air Navigation Service Provider managing French airspace)
DTA-only	Designated TA-only
E-ATMS	European Air Traffic Management System
EATMA	European Air Traffic Management Architecture
EHS	Extended Hybrid Surveillance

[3] Traffic Information Services – Broadcast, TIS-B Messages are note used for ACAS X.

[4] It is not used by ACAS Xa/Xo.

EUROCAE	EURopean Organisation for Civil Aviation Equipment A European standard-making organization. Its Working Group 75 (WG-75) is in charge of developing industrial standards for ACAS.
FAA	Federal Aviation Administration
FB	Functional Block
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
ID	IDentifier
INTEROP	Interoperability Requirements
IRS	Interface Requirements Specification
MOPS	Minimum Operational Performance Standards
NaN	Not a Number
NACp	Navigation Accuracy Category for Position
NACv	Navigation Accuracy Category for Velocity
NAR	Non-Altitude Reporting
NIC	Navigation Integrity Category
OFA	Operational Focus Area (SESAR)
OI	Operational Improvement
OSED	Operational Service and Environment Definition
RA	Resolution Advisory
RI	Reply Information
RTCA	RTCA Inc. (formerly Radio Technical Commission on Aeronautics) A US standard-making organization. Its Special Committee 147 (SC-147) is in charge of developing industrial standards for ACAS.
SC	Special Committee (RTCA)
SDA	System Design Assurance Level
SESAR	Single European Sky ATM Research Programme
SIL	Source Integrity Level
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPM	Signal Processing Module
SPR	Safety and Performance Requirements

SRS	System Requirement Specifications
STM	Surveillance and Tracking Module
TA	Traffic Advisory
TAD	Technical Architecture Description
TCAS	Traffic alert and Collision Avoidance System
TRM	Threat Resolution Module
TS	Technical Specification
UF	Up link Format
UF0	UF of Short Air surveillance (ACAS), interrogation from ACAS
UF11	UF of Mod S Only All Call
UF16	UF of Long Air-Air Surveillance (ACAS), interrogation from ACAS
US	United States
VRC	Vertical Resolution advisory Complement
WG	Working Group

Table 2: Acronyms and terminology

3 SESAR Solution Impacts on Architecture

The solution aims at improving on current Airborne Collision Avoidance for Commercial Air Traffic by taking advantage of optimized resolution advisories and of additional surveillance data, without changing the cockpit interface (same alerts and presentation).

Indeed, the performance of collision avoidance can be improved by:

- Using information from the more accurate surveillance source available. Currently collision avoidance alerts are based on a unique source (active Mode C/S interrogations). This is expected to improve marginally both safety and operational compatibility;

- Optimizing the rules for triggering an RA by applying state-of-the-art mathematical processes and modelling. Currently collision avoidance alerts are based on a series of empirical rules. This is expected to improve significantly both safety and operational compatibility.

This solution refers to ACAS Xa that is the variant of the ACAS X concept for Commercial Air Transport normal operations. ACAS X is an FAA currently-under-development new family of collision avoidance systems. ACAS Xa is an aircraft collision avoidance system being designed with the intention to be proposed as the next generation of TCAS II system with general equipage beginning in the 2020-2023 timeframe.[5] ACAS Xa implements the two improvements described above, with ADS-B surveillance as the additional surveillance source.

Each improvement is implemented by a different module of ACAS Xa. The Surveillance improvement is dealt with by the ***Surveillance and Tracking module (STM)***, which processes the raw surveillance data coming from the surveillance sensors. The RA improvement is dealt with by the ***Threat Resolution Module (TRM)***, which uses the estimated intruder parameters provided by the STM to choose an appropriate avoidance manoeuvre, if necessary.

Top level benefits, objectives and goals of ACAS X:

- Reduction of 'unnecessary' (nuisance) advisories by 50% (specifically for ACAS Xa);
- Improved adaptability to future operational concepts (specifically for ACAS Xa);
- Safety improvement by 20% (specifically for ACAS Xa);
- Adaptability of collision avoidance system to various classes of aircraft. Currently four classes of ACAS X are envisioned:
    - ACAS Xa (active) targeting the same classes of aircraft like the current TCAS II. In addition, there is an extra capability ACAS Xo, which will be implemented with ACAS Xa and is intended for specific operations that may interfere with the nominal collision avoidance logic, such as closely spaced parallel runway approach;
    - ACAS Xr targeting Rotor Craft;
    - ACAS Xu for Unmanned Aircraft Systems; and
    - ACAS sXu focusing on Small Unmanned Aircraft.
- Functional decoupling of the collision avoidance logic from the surveillance;

[5] ACAS Xa system installation on aircraft implies a TCAS Line Replaceable Unit change.

- Flexibility with respect to use of different surveillance sensors.

As it was mentioned, this TS is strongly focused on STM. Nevertheless, let's briefly remind TRM as well. TRM identifies threats and provides resolution guidance. TRM considers inputs from STM, current position and its uncertainty, current manoeuver of ownship (to prevent, for instance, descending in low altitude or rapid changing of manoeuver), as well as current manoeuver of intruders (in case of RA, for the intruders which coordinate). Up to 30 aircraft can be processed by TRM (up to 120 aircraft in the vicinity can be detected by STM). The STM report (the consolidated STM output / TRM input) is handed over to the TRM once per second.

In more detail, TRM processes STM report, assesses the input and generates alerts (TA, RA) when necessary. The assessment is based on Off-line costs table, which is pre-calculated[6]. The horizontal information is first converted to Tau (time to the separation infringement[7]) in the TRM. More precisely, a distribution of Tau is the result of the conversion – for each possible Tau (integer) between 0 s and 41 s (included) a probability of its occurrence is estimated.

The granularity[8] and the assessment of admissible advisories – the associated cost (presented in the above Off-line tables) were tuned during the system evaluation. This table is very extensive and this is the reason of ACAS Xa/Xo demands from a hardware point of view (memory, processor). The table contains assesment of possible recommended manoeuvers associated with discrete points which represents relative intruder states. Moreover, there is calculation and application of on-line cost which corrects off-line results in some special situations (for instance, descending is inhibited when ownship is under predefined altitude above ground).

So, each manoeuver has assigned appropriate cost which is derived from probabilistic consequence of the manoeuvre regarding *Clear of Conflict* status achievement. Probabilities of states from the STM report are combined with costs from the Off-line cost table. Moreover, the special limitations are considered by On-line costs which penalise some manoeuvers in specific situation (for instance low altitude...), and current RA (if any) and possibly coordination are taken into account. Finaly, the most suitable manoeuver, if any, is chosen and recommended.

3.1 Target Solution Architecture

3.1.1 SESAR Solution(s) Overview

Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations- ACAS Xa refers to the use of ACAS Xa, an airborne collision avoidance system which takes advantage of

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[6] Dynamic programming is used.

[7] In the TCAS II Tau is considered differently as time to Closest Point of Approach (CPA): an occurrence of minimum range between own TCAS II aircraft and the intruder. Thus, range at CPA is the smallest range between the two aircraft and time of CPA is the time at which this occurs. [33]

[8] The vertices / nodal points of the most important table are associated with the vector of these components: Tau, relative altitude, ownship vertical speed, intruder vertical speed, and information about a current RA.

optimised resolution advisories and of additional surveillance data, without changing the cockpit interface (i.e. same alerts and presentation in the current TCAS).

The architecture has been designed in the draft version of EATMA V13.0 / DS20. Therefore, the Change Requests (CRs) issued by the solution are expected to be endorsed at the end of it.

These CRs aim to:

- Update the A/C-54a EN by linking the latest version of the technical architecture elements.
- Include the relationship between the OIs CM-0808-a and CM-0808-o.

OI Step		OI description	Open CR
CM-0808-a		Improved Collision Avoidance for commercial air transport in standard operations (ACAS Xa)	CR 03548 Update CM-0808-a with link to CM-0808-o
	EN code	EN description	Open CR
	A/C-54a	Enhanced Airborne Collision Avoidance (ACAS)	CR 03547 Update of A/C-54a with architecture from PJ.11-A1

SESAR Solution ID and Title	Functional Blocks/Role impacted by the SESAR Solution (from EATMA)	Enabler ID (from EATMA)	Enabler Title (from EATMA)	Enabler coverage
PJ.11-A1: Enhanced Airborne Collision Avoidance for Commercial Air Transport normal operations - ACAS Xa	Airborne Collision Avoidance (ACAS Xa/Xo) (PJ.11-A1)	A/C-54a	Enhanced Airborne Collision Avoidance (ACAS)	Fully

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

Enabler	Opt/Req	Deviation
A/C-54a_Enhanced Airborne Collision Avoidance (ACAS)	Required	The CR on this EN aims to disconnect the old technical elements associated to it and to link the new designed technical architecture including the new ACAS Xa, the functions that it performs and the relevant system ports.

3.1.1.2 Relevant Use Cases

Operational Use Case	Description

None	*PJ.11-A1 is a technological solution that does not have to provide an OSED. Therefore, no operational use cases were expected to be designed or linked.*

System Process	Description
[NSV-4] Encounter between ownship and an a/c with Mode C/S only	This technical use case describes the process when there is an encounter between ownship and an a/c with Mode C/S only
[NSV-4] Encounter between ownship and either an a/c with ACAS (with ADS-B Out) or a/c without ACAS (with ADS-B Out)	This technical use case describes the process in case there is an encounter between ownship and either an a/c with ACAS (with ADS-B Out) or a/c without ACAS (with ADS-B Out).

3.1.1.3 Applicable standards and regulations

Key applicable standard for this solution is:

- RTCA DO-385 / EUROCAE ED-256

Other relevant Standards – Communication Protocols (SESAR) are:

- ACAS air
- ACAS ground
- ACAS status
- ADS-B
- TCAS Receiver
- TCAS Transmitter

3.1.2 Capability Configurations required for the SESAR Solution

ACAS Xa for Commercial A/C		En-RouteTerminal Airspace		
CC	**Op Env**	**Capability**	**Node**	**Stakeholder**
Civil Aircraft (Ownship)	En-Route; Terminal Airspace	Mid-Air Collision Avoidance	Airspace User Operations; Flight Deck	Civil Scheduled Aviation
Civil Aircraft with ACAS	En-Route; Terminal Airspace	Mid-Air Collision Avoidance	Airspace User Operations; Flight Deck	Civil Scheduled Aviation;

Civil Aircraft with Mode C/S only	En-Route; Terminal Airspace	Mid-Air Collision Avoidance	Airspace User Operations; Flight Deck	Civil Scheduled Aviation
Civil Aircraft without ACAS with ADS-B Out	En-Route; Terminal Airspace	Mid-Air Collision Avoidanc	Airspace User Operations; Flight Deck	Civil Scheduled Aviation

3.2 Changes imposed by the SESAR Solution on the baseline Architecture

Enabler	Element type	Element name	Impact	Change
A/C-54a (CR)	Enhanced Airborne Collision Avoidance (ACAS)			
	FB	Airborne Collision Avoidance (ACAS Xa/Xo) (PJ.11-A1)	Update	Enhancement of the ACAS with the ACAS Xa system
	Function	Actively provide collision avoidance	Introduce	New Function for the ACAS Xa/Xo FB
	Function	Announce Traffic, Traffic	Introduce	New Function for the ACAS Xa/Xo FB
	Function	Highlight intruder	Introduce	New Function for the ACAS Xa/Xo FB
	Function	Instruct manoeuvre to be taken	Introduce	New Function for the ACAS Xa/Xo FB
	Function	Issue a Resolution Advisory	Introduce	New Function for the ACAS Xa/Xo FB
	Function	Issue Clear of Conflict	Introduce	New Function for the ACAS Xa/Xo FB
	Function	Issue Traffic Advisory	Introduce	New Function for the ACAS Xa/Xo FB

4 Technical Specifications

According to ADD document [34], the STM is responsible for the following functions:

- Based on the incoming active and passive surveillance data as well as own navigational data, track relative 3D position and velocity of ownship and targets and maintain actual information about intruders and ownship state.
- Regularly pass relevant track file information to threat logic (STM Report).

In addition, STM receives ACAS Xo designation/undesignation requests from on-board Aircraft Surveillance Applications (ASA) interface, process them and transmit the designation information to TRM for further processing. Additionally, intruder position data for the display is generated by the STM.

There are some portions of surveillance that are managed outside of STM, and are expected not to be prescriptive, providing manufacturers with certain level of flexibility to design a system that takes into account a specific system attributes. Such functions are referred as Front End Surveillance, and MOPS (Vol I, 2.2.4.8) provides following examples of such functions:

- Hybrid Surveillance
- Mode S Interrogation Rate determination
- Mode C whisper-shout sequence determination
- DF-11 squitter monitoring and Mode S acquisition
- ADS-B report generation

As stated in the Introduction, ACAS X introduces conceptual changes with respect to TCAS II in the system functional architecture, collision avoidance logic, and surveillance functions.

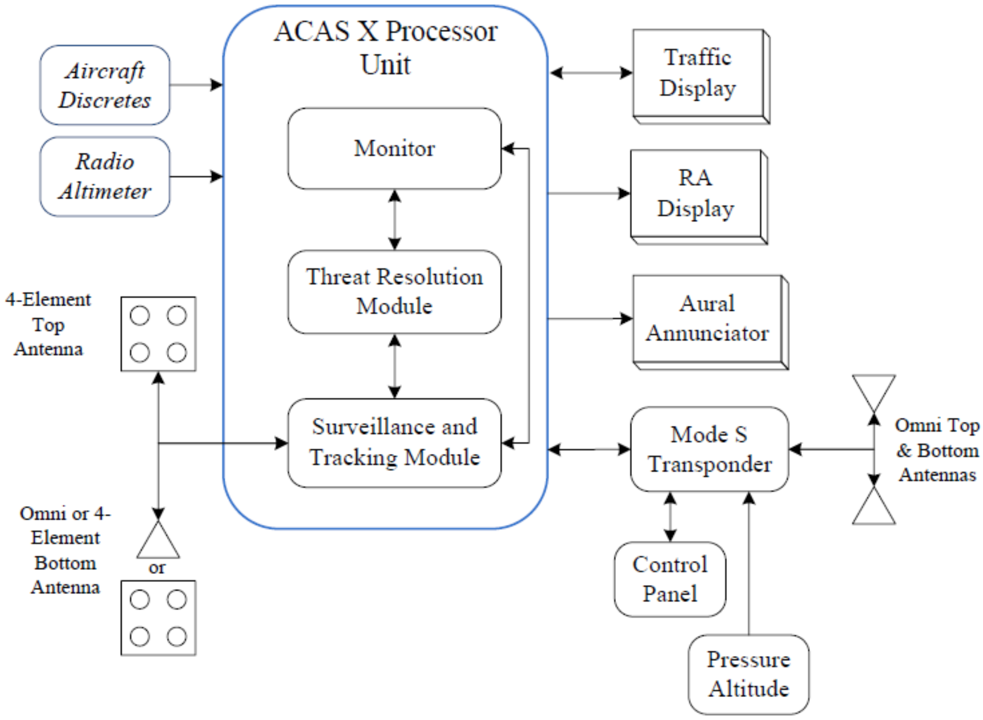


Figure 1: Block diagram of an example of ACAS Xa (from [32]).

An essential modification of the system architecture is decoupling of surveillance functions implemented in the Surveillance & Tracking Module (STM) from collision avoidance logic residing within the Threat Resolution Module (TRM). The high-level block diagram of ACAS Xa is shown in Figure 1 (from ACAS X ConOps [32]). In ACAS X the TRM is provided by STM report with a probabilistic distribution of estimated intruders' states through a standardized interface and TRM is thus functionally independent of the surveillance methods used to determine this information[9].

Second conceptual change is the new collision avoidance logic where a set of hard-coded rules used in TCAS II is replaced by numeric lookup tables optimised with respect to a probabilistic model of the airspace and a set of safety and operational considerations.

Finally, ACAS X surveillance is intended to handle multiple approved surveillance sources when they are installed on the aircraft. Within ACAS X ConOps [32], it is formulated in terms of "Plug and Play Surveillance" concept:

"All ACAS X surveillance sources will be received by (i.e., plugged into) a single version of the STM. The STM will automatically recognize each surveillance message that has been received, process it, and use it to track the associated intruder without the need for manual configuration or additional programming."

Current design description of ACAS Xa considers position measurement based on the Mode S or Mode C active interrogation of intruder's transponder and ADS-B measurements.

[9] In TCAS II, a part of this processing is done inside Collision Avoidance System.

According the ADD document [34], STM stores all information for a single intruder in a data structure called **Target.** Within this Target data structure there may be one or more **Track Files** typically corresponding to different type of surveillance sensors, and a dedicated data structure with correlated data corresponding to different track files which is used for cross-check (validation) of information from different surveillance sources.

Beyond the Target data structures associated with tracked intruders, STM maintains a separate data structure dedicated for ownship data.

According to ADD [34], STM has three main external interfaces:

- With own navigation sensors: STM receives input data from own navigation sensors: barometric and radar altimeters, GNSS, heading and own Mode S address.
- With Signal Processing Module (SPM): SPM communicates with installed surveillance sensors and performs low level processing (e.g., decoding, formatting) of surveillance measurements and transmission requests. SPM also performs measurements of intruder range and bearing. This is also referred to as Front End Surveillance.
- With TRM: the primary STM output (surveillance report) is provided to TRM. Coordination input data from intruders, the ownship data to be processed by the transponder, as well as STM display data for onboard display (see Appendix B, B.1), are part of the surveillance report. To simplify the interfacing of STM and TRM, there is shared data structure defined in the Appendix E of ADD [34].

The high-level functional architecture of STM according to ADD [34] is shown in Figure 2. Note that procedurally there are two different parts of the STM:

- The first part processes the surveillance and own sensors inputs and maintains the ownship and targets data structures updated. This part represents an event-driven process triggered by reception of a new sensors measurement.
- The second part uses the above mentioned data structures as input and generates the surveillance report for TRM. This process is driven by TRM requirements and is running regularly with a pre-defined rate of 1Hz.

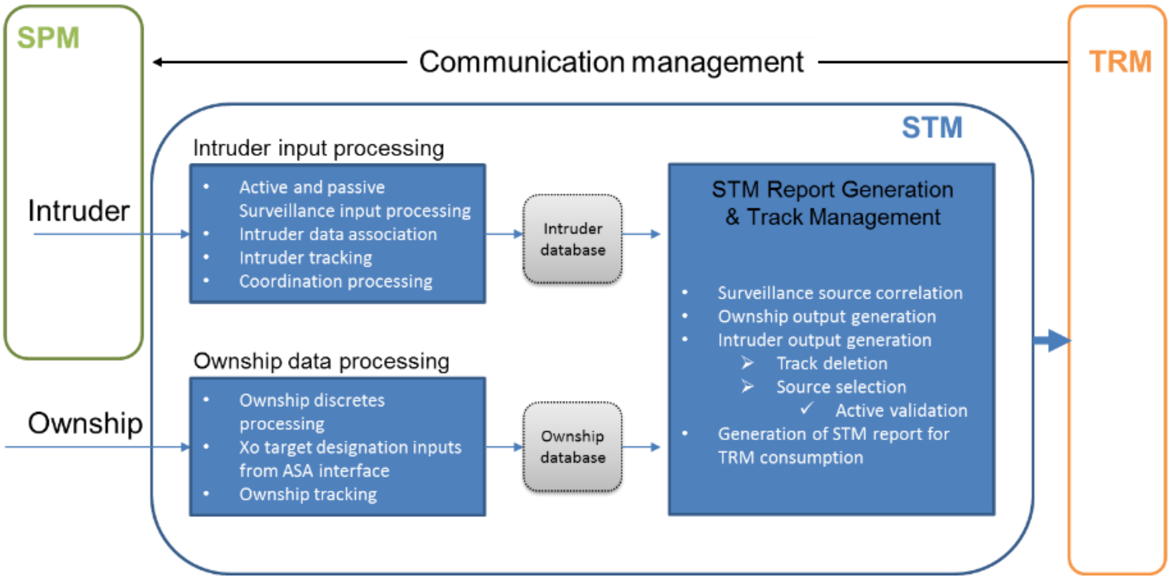


Figure 2: High-level STM functional architecture.

The high-level STM functional architecture shown in Figure 2 introduces the following main functional blocks (data handling):

Intruder input processing

- Process all defined types of inputs (measurements) from SPM.
- Identify the type of input and associated surveillance sensor
- Associate measurements to existing target and track files (if they already exist)
- Initiate a Track File
- Initiate a Target data structure
- Update a Track File with a new intruder's state estimation
- Associate the observations from surveillance sources to appropriate track.
- Process coordination messages from intruder

Note that in reality each of the above items represents a set of functions specific for data from various surveillance sensors.

Ownship data processing

- Process inputs from on-board navigation sensors: barometric and radio altimeters, WGS84 sensor, and heading[10].
- Initiate ownship track file
- Update ownship track file.

[10] Note, that only barometric altitude and heading are tracked by the trackers, radio altitude and WGS84 are STM inputs supporting the calculations.

- Process target designation/undesignation inputs form ASA interface[11]

Track management and STM report generation

- Perform the surveillance source correlation
- For the common reference time compute the estimations of the target's state based on the different Track Files.
- Initiate/update the specific data structure with the correlated state estimations.
- Generate ownship output
- Generate intruder output
- Process all targets data structures and validate available information
- For each intruder use the best available information to create a probabilistic distribution of its estimated state.
- Create surveillance report containing probabilistic information about all relevant intruders.
- Create surveillance report to be used for target / intruder display.

4.1 Functional architecture overview

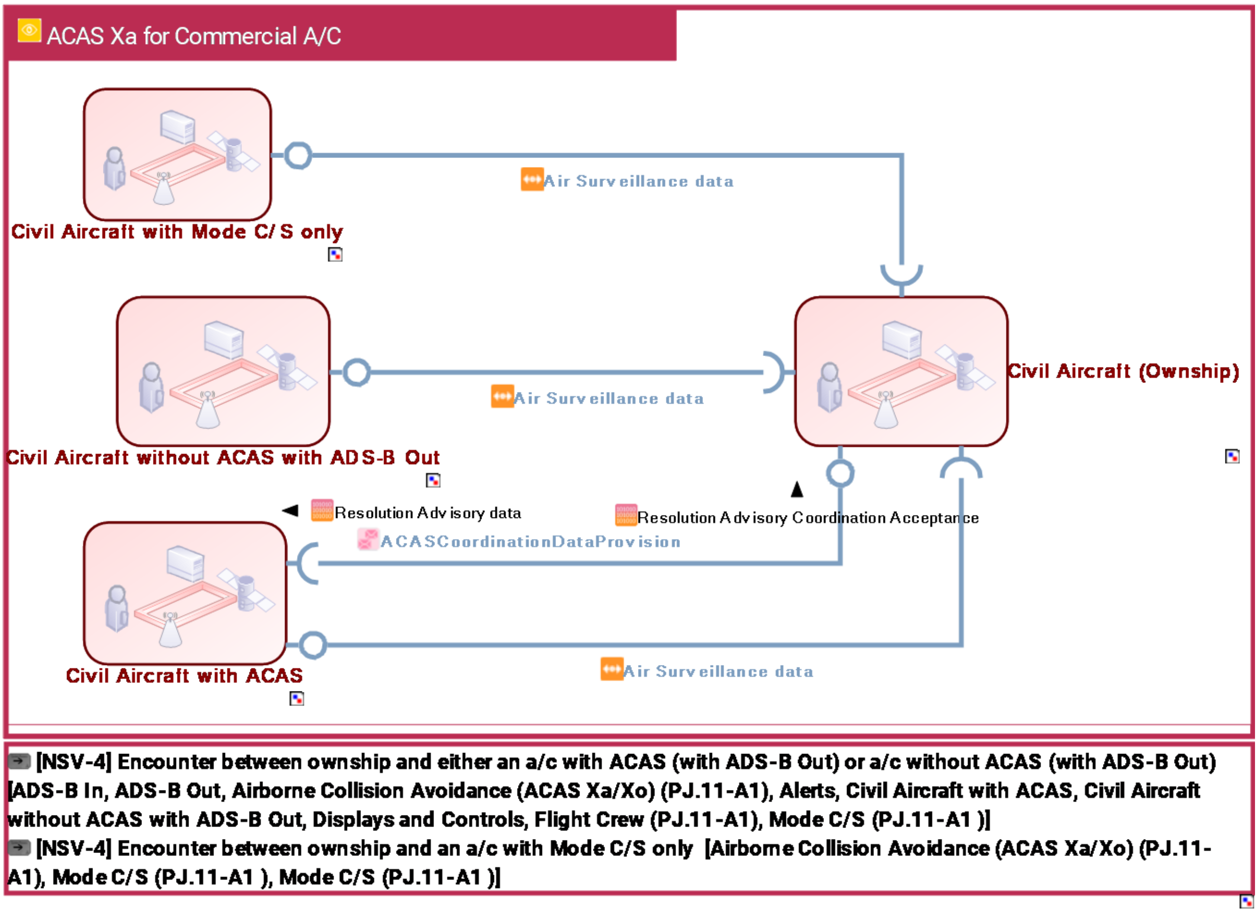
Role	Functional Block	Function
[NSV-4] Encounter between ownship and an a/c with Mode C/S only		
	Airborne Collision Avoidance (ACAS Xa/Xo) (PJ.11-A1)	
	Mode C/S (PJ.11-A1)	Mode C/S
	Mode C/S (PJ.11-A1)	Mode C/S
[NSV-4] Encounter between ownship and either an a/c with ACAS (with ADS-B Out) or a/c without ACAS (with ADS-B Out)		
	ADS-B In	ADS-B In
	ADS-B Out	ADS-B Out
	Airborne Collision Avoidance (ACAS Xa/Xo) (PJ.11-A1)	Actively provide collision avoidance; Announce Traffic, Traffic; Highlight intruder; Instruct manoeuvre to be taken; Issue a Resolution Advisory; Issue Clear of Conflict Issue Traffic Advisory;

[11] But ACAS Xo functionality is out of scope of the document, as it was mentioned.

	Alerts	Alerts
	Displays and Controls	Displays and Controls
Flight Crew (PJ.11-A1)		Achieve visual acquisition; Continue flying the A/C; Follow RA instruction; Notice the TA; Prepare for potential collision avoidance manoeuvre
	Mode C/S (PJ.11-A1)	Validate ADS-B data

4.1.1 Resource Connectivity Model

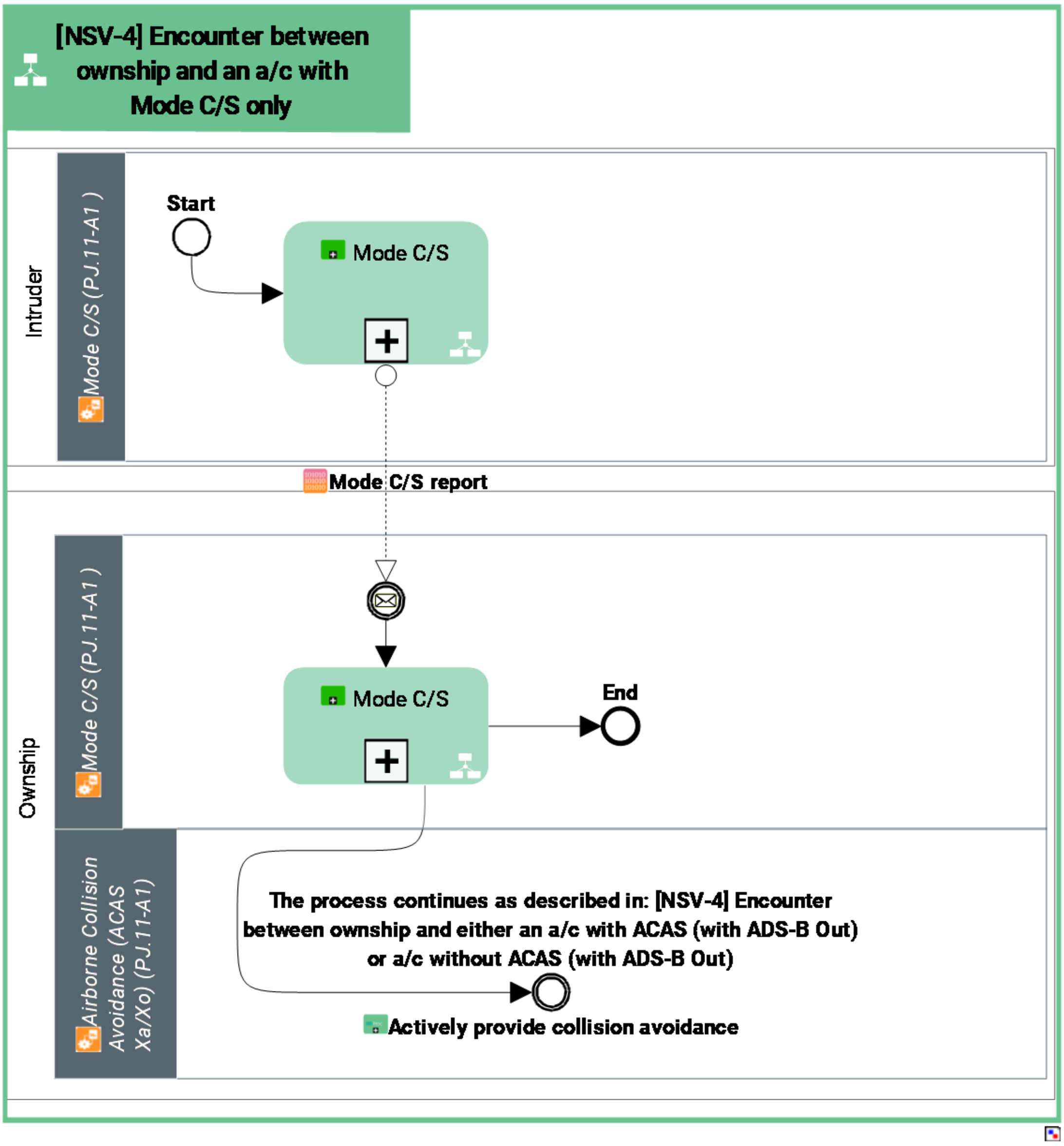
This NSV-1 shows the resource connectivity diagram of ACAS Xa



4.1.2 Resource Orchestration view

4.1.2.1 [NSV-4] Encounter between ownship and an a/c with Mode C/S only

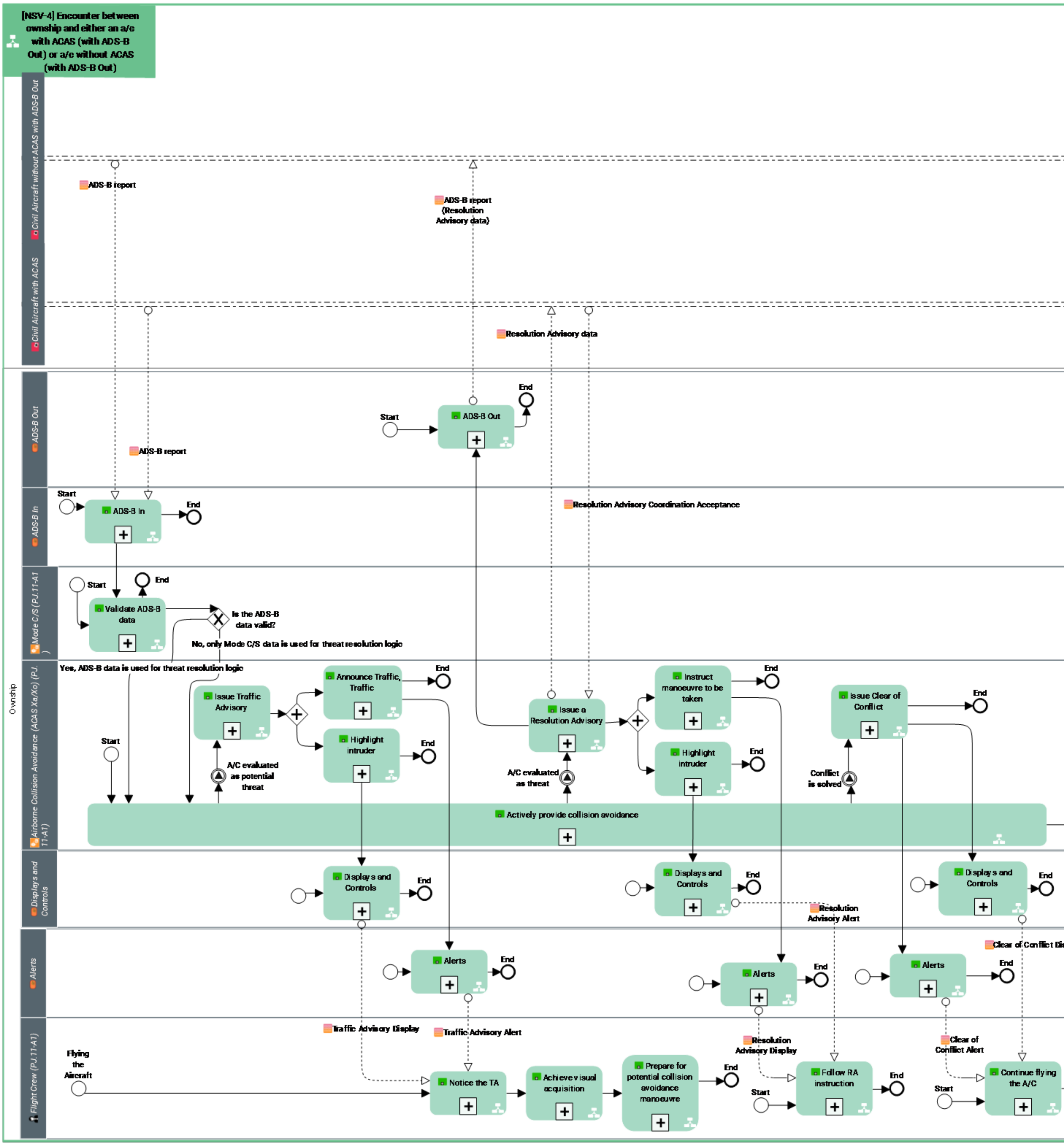
This technical use case describes the process when there is an encounter between ownship and an a/c with Mode C/S only



Function	Description
Mode C/S	Mode C/S

4.1.2.2 [NSV-4] Encounter between ownship and either an a/c with ACAS (with ADS-B Out) or a/c without ACAS (with ADS-B Out)

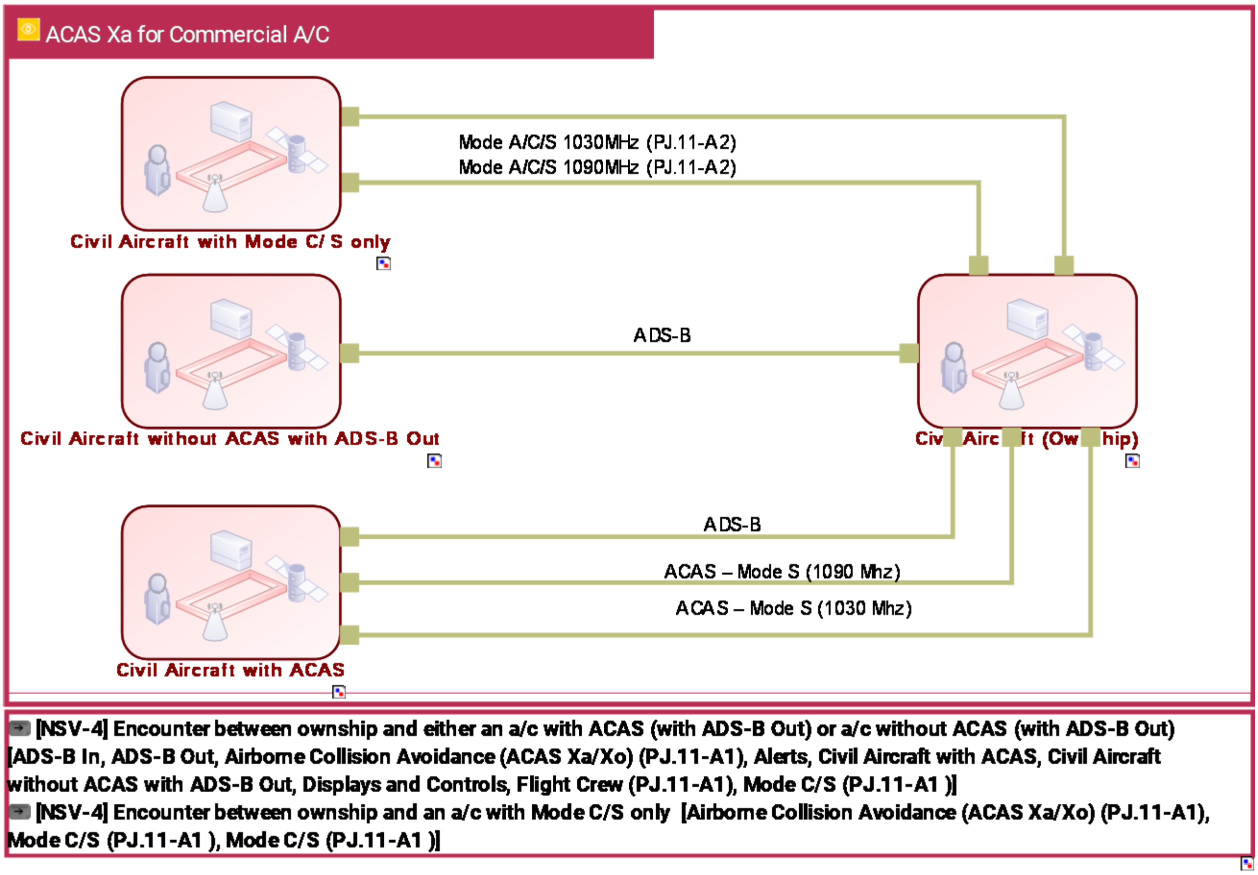
This technical use case describes the process in case there is an encounter between ownship and either an a/c with ACAS (with ADS-B Out) or a/c without ACAS (with ADS-B Out).



Function	Description
Achieve visual acquisition	To achieve visual acquisition of the potential thread A/C
Actively provide collision avoidance	Refers to intended function of ACAS, i.e. to detect and track surrounding traffic and if another airborne aircraft is a potential threat, then: (1) to issue TA to help pilot to achieve visual acquisition and prepare for potential avoidance maneuver, (2) if a maneuver becomes necessary, issue an RA instructing pilot to climb or descend to maintain a safe distance
ADS-B In	The function supporting the reception and processing (e.g. for ATSAW Spacing...) of surrounding aircraft traffic or ground mobile transmitting their position via ADS-B Out broadcasted data
ADS-B Out	The capability for a non-solicited aircraft to broadcast surveillance data (e.g. Latitude/Longitude, Speed...)
Alerts	The function providing Visual and/or Audio Alerts to the Flight Crew.
Announce Traffic, Traffic	To announce with voice inside the cockpit "Traffic Traffic"
Continue flying the A/C	To continue flying the A/C
Displays and Controls	The function centralising HMI related functions for avionics including graphic user interface.
Follow RA instruction	Flight Crew (or autopilot) is obliged to perform once ACAS triggers an RA in order to avoid the collision.
Highlight intruder	To highlight the intruder on a traffic display/CDTI
Instruct manoeuvre to be taken	To instruct the manoeuvre to take to maintain safe distance using display announcements
Issue a Resolution Advisory	To issue a Resolution Advisory after an a/c is evaluated as a threat
Issue Clear of Conflict	To issue Clear of Conflict once the conflict has been resolved
Issue Traffic Advisory	A Traffic Advisory is issued after the evaluation of an A/C being a potential threat
Notice the TA	To notice the Traffic Advisory alert issued by ACAS Xo
Prepare for potential collision avoidance manoeuvre	To prepare for potential collision avoidance manoeuvre
Validate ADS-B data	ADS-B data is actively validated (cross-checked) through Mode S interrogation.

4.1.3 Infrastructure connectivity model

This NSV-2 shows the resource connectivity diagram of ACAS Xa



4.1.4 Service view

4.1.4.1 Service description

Service	Service description
ACASCoordinationDataProvision	The ACASCoordinationDataProvision service notifies the Resolution Advisory data to those aircraft that are intended to get it when a risk collision situation is happening. See [40], Appendix A.

4.1.4.2 Service Provisioning

Interaction	Consumer CC	Consumer System	Provider CC	Provider System
Air Surveillance data.Civil Aircraft (Ownship)_CC and Civil Aircraft with Mode C/S only_CC	Civil Aircraft (Ownship)	Aircraft	Civil Aircraft with Mode C/S only	Aircraft

Interaction	Consumer CC	Consumer System	Provider CC	Provider System
ACASCoordinationDataProvision.Civil Aircraft with ACAS_CC and Civil Aircraft (Ownship)_CC	Civil Aircraft with ACAS	Aircraft	Civil Aircraft (Ownship)	Aircraft
Air Surveillance data.Civil Aircraft (Ownship)_CC and Civil Aircraft with ACAS_CC	Civil Aircraft (Ownship)	Aircraft	Civil Aircraft with ACAS	Aircraft
Air Surveillance data.Civil Aircraft (Ownship)_CC and Civil Aircraft without ACAS with ADS-B Out_CC	Civil Aircraft (Ownship)	Aircraft	Civil Aircraft without ACAS with ADS-B Out	Aircraft

4.1.4.3 Service Realization

4.1.4.3.1 Interaction ACASCoordinationDataProvision.Civil Aircraft with ACAS_CC and Civil Aircraft (Ownship)_CC

System Port: ACAS at Civil Aircraft (PJ.11-A1)_CC

Protocol Stack	Protocol
ACAS – Mode S (1030 Mhz)	
	UF16
ACAS – Mode S (1090 Mhz)	
	DF16

4.1.4.3.2 Interaction Air Surveillance data. Civil Aircraft (Ownship)_CC and Civil Aircraft with ACAS_CC

System Port: ADS-B_IN at Civil Aircraft (Step 2) (PJ.11-A1)_CC

Protocol Stack	Protocol
ADS-B	
	DF17
	DF18
	DF19[12]

System Port: ADS-B_OUT at Civil Aircraft (Step 2) (PJ.11-A1)_CC

Protocol Stack	Protocol

[12] The DF19 is used by the ADS-B IN and OUT system ports for the position reporting, not by the ACAS Xa/Xo. This system port uses UF16 and DF16.

ADS-B	
	DF17
	DF18
	DF19[13]

4.1.4.3.3 Interaction Air Surveillance data. Civil Aircraft (Ownship)_CC and Civil Aircraft with Mode C/S only_CC

System Port: MODE_A/C/S at Civil Aircraft (Step 2) (PJ.11-A1)_CC

Protocol Stack	Protocol
Mode A/C/S 1030MHz	
	UF00
	UF11
	UF16
Mode A/C/S 1090MHz	
	DF00
	DF11
	DF16

System Port: MODE_A/C/S at Civil Aircraft (Step 2) (PJ.11-A1)_CC

Protocol Stack	Protocol
Mode A/C/S 1030MHz	
	UF00
	UF11
	UF16
Mode A/C/S 1090MHz	
	DF00
	DF11
	DF16

4.1.4.3.4 Interaction Air Surveillance data. Civil Aircraft (Ownship)_CC and Civil Aircraft without ACAS with ADS-B Out_CC

System Port: ADS-B_IN at Civil Aircraft (Step 2) (PJ.11-A1)_CC

Protocol Stack	Protocol

[13] The DF19 is used by the ADS-B IN and OUT system ports for the position reporting, not by the ACAS Xa/Xo. This system port uses UF16 and DF16.

ADS-B	
	DF17
	DF18
	DF19[14]

System Port: ADS-B_OUT at Civil Aircraft (Step 2) (PJ.11-A1)_CC

Protocol Stack	Protocol
ADS-B	
	DF17
	DF18
	DF19

4.2 Functional and non-Functional Requirements

The intention of this document is not to duplicate any of already existing requirements in System Requirements Specification [35] or MOPS (DO-385/ED-256, Vol I) [33], but rather provide a functional view on the STM design defined in ADD (DO-385/ED-256, Vol II) [34]. Therefore this section addresses a subset of functional requirements resulting from the ACAS X ConOps [32], MOPS (DO-385/ED-256, Vol I) [33] and a STM design described in the ADD document (DO-385/ED-256, Vol II) [34] which are complemented with a simplified description of the actual implementation of STM according the ADD algorithms.

First of all, the prerequisites associated with the STM design as described in the ADD [34][15] are provided:

ASM-PJ.11-A1-001 Approved Surveillance Sources

There are two approved surveillance sources for ACAS Xa: ADS-B and active interrogation of intruder's transponder (Mode S or Mode C). The system will provide basic resolution advisories only if active surveillance is provided.

As described above, one of the key objectives of ACAS X STM design is to enable plug and play surveillance concept which will allow, especially for unmanned system, straightforward use of additional surveillance sensors (e.g., non-cooperative). This objective is taken into account in

[14] The DF19 is used by the ADS-B IN and OUT system ports for the position reporting, not by the ACAS Xa/Xo. This system port uses UF16 and DF16.

[15] These prerequisites are not considered as true assumptions (so they are not listed in the chapter 6) because they are associated with the STM, which especially means that the prerequisites are part of ACAS Xa – they are not assumed by the whole system, they are inside the system. Of course, from STM point of view they could be considered as assumptions.

formulation of the requirements, however, as only ADS-B/ADS-R[16] and TCAS-like active interrogation are assumed for ACAS Xa, only these two types of surveillance inputs are considered in this document.

ASM-PJ.11-A1-002 Time of Applicability of Surveillance Measurements

All surveillance data from SPM and own sensors will be provided to STM with the associated time of applicability.

ASM-PJ.11-A1-003 STM Surveillance Intruder Input Data

The following types of input data are assumed from SPM:

- Data from Mode S active interrogation
- Data from Mode C active interrogation
- ADS-B In data:
  - Airborne Position Report
  - Airborne Velocity Report
  - Mode Status Report
- ADS-R (rebroadcast)

Information required within each of this input is described in Appendix A.

ASM-PJ.11-A1-004 STM Own Sensors Input Data

The following types of input data are assumed from ownship sensors:

- Barometric altitude observations
- Radio altitude observation
- Heading observation
- WGS84 observation (latitude, longitude, E/W velocity, N/S velocity) via GNSS
- Ownship discretes

Information required within each of this input is described in Appendix A.

ASM-PJ.11-A1-005 STM Coordination Input

ReceivedCoordinationData structure contains coordination data from a target – see Appendix B, B.2. The intruder reports include coordination information (vertical resolution complement).

ASM-PJ.11-A1-006 STM Surveillance Report Update

TRM requires the surveillance report with a fixed update rate once per second (1 Hz).

ASM-PJ.11-A1-007 Front End Surveillance

It is assumed, that ACAS Xa will be using hybrid and extended hybrid surveillance. This functionality, as well as other functions (Mode S interrogation rate determination, Mode C whisper-shout sequence determination, DF11 squitter monitoring, Mode S acquisition and ADS-B report generation) will be handled by Front End Surveillance, which is not part of STM.

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[16] ADS-R – not in Europe environment.

4.2.1 Intruder Input Processing

This functional block ensures correct processing of all surveillance measurements and their association to the existing Track Files (and Target) when possible, as well as performs the intruder tracking – the core function of surveillance module.

Tracking methods vary in general according the type of surveillance information and measurements/sensors characteristics. In this context and due to TCAS/ACAS X approach to collision avoidance resolution, the horizontal and vertical components of the intruders' states are always tracked separately.

For **active (both Mode S and Mode C) surveillance** there are three trackers considered in ADD, two for horizontal dimensions and one for vertical [34]:

- Vertical tracker is based on linear Kalman filter
- Two horizontal trackers use both an unscented Kalman filter method, however a different approach is adopted in the application of the method:
  - Cartesian tracker is designed to handle better the poor quality of bearing measurements in active surveillance. Although it tracks the complete 6 dimensional state (relative x, y, z, v_x, v_y, v_z), it is used to provide azimuth and cross ground rate of the intruder.
  - Range tracker is then used to estimate relative horizontal range and horizontal range rate of the intruder.

  The outputs of the two trackers are combined at the time of Surveillance Report generation (within creation of the Intruder file).

For **passive (both ADS-B and ADS-R) surveillance** there are two trackers: the vertical is identical to the one used for active surveillance (as the source of information is the same); and the horizontal uses also Kalman filter method and is based on algorithms described in Appendix C of RTCA DO-317B (MOPS for Aircraft Surveillance Applications Systems).

The key difference with respect to TCAS II surveillance is that the tracking output includes the uncertainty of this state (expressed in terms of covariance matrix), in addition to the estimated state.

The STM processes **coordination data** that has been received from a target aircraft. Valid data are associated to particular target based on Mode S address and further processed for provision to TRM.

4.2.1.1 Intruder Input Processing Requirements

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0001
Title	Surveillance Input Processing
Requirement	STM for ACAS Xa shall be able to process at least the following surveillance inputs: • Position measurements based on the active interrogation of intruder's transponder (both Mode C and Mode S measurement)

	• Airborne Position Report (ADS-B) • Airborne Velocity Report (ADS-B) • Mode Status Report (ADS-B)
Status	<Validated>
Rationale	Processing of active surveillance inputs is standard part of TCAS and one of the key features of ACAS Xa is ability to process passive surveillance inputs.
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1497[17]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm, 3meIPq6rM55B, 2iiJ(qt4TLVo
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, qjiJLut4Tn8p, kBCe1AC5TvfE
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ- PJ.11-A1-TS-STMa.0002
Title	Asynchronous Surveillance Input Processing
Requirement	STM shall be able to process different surveillance inputs asynchronously.
Status	<Validated>
Rationale	Updates of different sources are not synchronized. Therefore ACAS Xa needs to process inputs asynchronously to have the newest surveillance data.
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1

[17] If it is not individually specified, all “SPR-INTEROP/OSED Requirements“ are referred based on [33].

<SATISFIES>	<ATMS Requirement>	1499, 1500
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm, 3meIPq6rM55B, 2iiJ(qt4TLVo
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, qjiJLut4Tn8p, kBCe1AC5TvfE
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0003
Title	Type of input data identification
Requirement	STM shall be able to identify unambiguously the type of sensor (input) associated with the received input data.
Status	<Validated>
Rationale	The input data identification is necessary for correct function of trackers.
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1497
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm, 3meIPq6rM55B, 2iiJ(qt4TLVo
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, qjiJLut4Tn8p, kBCe1AC5TvfE
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0004
Title	Surveillance Input Data Association
Requirement	STM shall be able to associate the received surveillance measurement with the existing Track File and detect when such association is not possible.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	2600, 2601, 2602
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0005
Title	Track Files types
Requirement	STM for ACAS Xa shall support three types of Track Files: two for active surveillance (data obtained using active Mode S and Mode C interrogation of intruders) and one for ADS-B surveillance.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1497
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0006
Title	Track Files initiation

Requirement	For each type of Track File STM shall provide a function to initiate this Track File under condition that defined initiation criteria are satisfied.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1325, 1367, 1368, 1372,
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0007
Title	New Track File Association
Requirement	STM shall be able to associate the new Track File with the existing Target and detect when such association is not possible.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	2600, 2601, 2602
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0008
Title	Target data structure initiation
Requirement	STM shall provide function to create a new Target data structure when the new Track File does not associate with existing Targets.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	2600, 2601, 2602
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0009
Title	Track Files update
Requirement	For each type of Track File STM shall provide functions to update Track File based on received new surveillance measurement.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1329, 1377, 1416
< ALLOCATED_TO >	<Enabler>	AC/54-A

<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0010
Title	Outliers detection
Requirement	For each type of Track File STM shall provide functions to detect and process outliers in received measurements.
Status	<Validated>
Rationale	Derived through abstraction of ADD – Mahalanobis distance is used because it takes into account standard deviation.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 2.2.5.1.1
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0011
Title	Separated horizontal and vertical tracking
Requirement	The tracking shall be performed separately for vertical dimension and horizontal plane.
Status	<Validated>
Rationale	Derived through abstraction of ADD –there are two horizontal trackers (range and Cartesian) implemented for active surveillance and one for ADS-B data. Vertical tracker is essentially the same for both type of surveillance as the provided vertical information is the same.

Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1843
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm, 3meIPq6rM55B, 2iiJ(qt4TLVo
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, qjiJLut4Tn8p, kBCe1AC5TvfE
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0012
Title	Coasting function
Requirement	For each type of Track File STM shall provide coasting functions to compute state estimation at the given reference time.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1397
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0013
Title	State estimation in a Track File

Requirement	Both horizontal and vertical position/velocity estimations to be stored in a Track File shall be computed as a (mean) value and the related estimated uncertainty formulated in terms of covariance.
Status	<Validated>
Rationale	Derived through abstraction of ADD – this is an important difference with respect to TCAS II where only the estimated value is required. In ACAS Xa it is required to estimate also the related uncertainty.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 2.2.5.1.3
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0030
Title	Tracking capacity
Requirement	STM shall be able to track at least 30 intruders.
Status	<Validated>
Rationale	Derived through abstraction of MOPS.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 2.2.5.6.1.3.1
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr

<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0031
Title	Target Air/Ground status
Requirement	STM shall be able to determine “in air” and “on ground” status of intruder.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1307-1315
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0033
Title	Coordination information
Requirement	STM shall be able to correctly handle and process coordination information from intruder and pass it to TRM.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1993, § 2.4.2.2.2.1
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm, CpelCr6rMPUB
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, qjiJLut4Tn8p
<ALLOCATED_TO>	<Service>	WCrEk5q2TrYJ
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0035
Title	Conversion of intruder state
Requirement	STM shall be able to determine if the intruder is in polar region.
Status	<Validated>
Rationale	Derived through abstraction of ADD
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	Algorithm 46[18]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm, 3melPq6rM55B
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, qjiJLut4Tn8p
<ALLOCATED_TO>	<Resource Interaction>	N/A

4.2.2 Ownship Data Processing

[18] See [34].

This functional block contains processing of inputs from own navigation sensors and storing of the estimated ownship state in the dedicated data structure. This information is used for STM Report generation but also to convert ADS-B surveillance measurements to the relative coordinates within ADS-B tracking.

For both ownship vertical state estimation and heading estimation a standard Kalman filter is used (the same method which is used for the intruder vertical state estimation). The tracking of WGS84 (GNSS) position is not implemented.

4.2.2.1 Ownship Tracking Requirements

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0016
Title	Own Sensors Input Processing
Requirement	STM for ACAS Xa shall be able to process at least the following inputs from own sensors: • Ownship discretes • Barometric altitude observations • Radio altitude observation • Heading observation • WGS84 observation (latitude, longitude, E/W velocity, N/S velocity)
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1497
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0017
Title	Ownship Track File initiation
Requirement	STM shall provide function to initiate Ownship Track File under condition that defined initiation criteria are satisfied.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 1.4.2.5.3[19], § 2.4[20]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0018
Title	Ownship Track File update
Requirement	For each type of own sensor STM shall provide functions to update Ownship Track File based on received new sensors measurement.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[19] See [33].

[20] See [34].

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 1.4.2.5.3[21], § 2.4[22]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0032
Title	Ownship Air/Ground status
Requirement	STM shall be able to determine ownship “in air” and “on ground” status.
Status	<Validated>
Rationale	Derived through abstraction of MOPS[23] – below 50 ft AGL, all traffic is regarded as on ground. Designation of traffic when ownship is on-ground is permitted. However, ACAS Xa surveillance may not support on-ground traffic.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1319-1323
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[21] See [33].

[22] See [34].

[23] Chapters 2.2.4.6.3 and 2.2.8.5

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0036
Title	Conversion of ownship state
Requirement	STM shall be able to determine if the ownship is in polar region.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	Algorithm 46[24]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

4.2.3 Track Management & STM Report Generation

Track management addresses the maintenance of existing Targets stored in memory and production of STM reports. Prior to generating the STM report for TRM consumption, STM performs surveillance source correlation determining if two targets represent a single intruder or if two aircraft are incorrectly represented by a single target. This correlation processing is addressed in ADD (DO-385/ED-256, Vol II) [34], in Appendix C.

Then it generates the ownship and intruder outputs for STM report itself. Within intruder output generation, several tasks are performed such as: stale tracks removal, and best source for STM report is selected. ADS-B surveillance data are only used if they pass a number of checks:

1. A comparison of ADS-B track with the Mode S track on the same target

[24] See [34].

2. Minimum data quality check, which compares quality of received ADS-B data with minimum ADS-B data quality parameters defined in ADD (DO-385/ED-256, Vol II) [34], Appendix F – Parameters File. Following values are required:

   Comparing to Run 14, NACp – Navigation Accuracy Category for Position – is not associated with the accuracy of the ADS-B data, which is used in corresponding algorithms. NACp is used for the minimum data quality check only. For purpose of calculations the accuracy is internally set to NACp = 7 level for all data (regardless with higher or *lower* NACp)[25].

If the conditions for inclusion to STM Report are satisfied, creation of the new data structure succeeds (Intruder File) which is inserted in the Surveillance Report. In addition to a set of data fields described in detail in Appendix B, an Intruder File contains a probabilistic distribution of target's vertical state (sigma sample of 5 weighted states similarly as for ownship), and a distribution of horizontal states (sigma sample of 9 weighted states (relative position and velocity in North/South and East/West Cartesian coordinates)).

As described above the STM report generation is performed at a constant rate (1 Hz) and provides ownship and surveillance information needed by collision avoidance logic for the given reference time.

4.2.3.1 Track Management & STM Report Generation Requirements

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0014
Title	Active validation data structure initiation
Requirement	STM for ACAS Xa shall provide a capability to create a dedicated data structure containing a series of passive and active state estimations at the same times of applicability obtained independently from passive and active surveillance Track Files.
Status	<Validated>
Rationale	Derived through abstraction of ADD – the active validation data structure is used within the surveillance report generation for cross-validation of passive surveillance data.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1

[25] See *update_sigma_pos*, ADD (DO-385/ED-256, Vol II) [34], Appendix F – Parameters File and Algorithm 68.

<SATISFIES>	<ATMS Requirement>	Algorithm 120[26]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0019
Title	Surveillance Report generation
Requirement	STM shall provide the function to create Surveillance Report in the format required by TRM[27] and the display using the STM data structures (Targets, Ownship Track File) as input.
Status	<Validated>
Rationale	Derived through abstraction of ADD – section 2.2.3 and associated algorithms were modified to prohibit vertical arrow fluctuation
Category	<Interface>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	1993, 1994
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

[26] See [34].

[27] Refer to Appendix B for format definition.

Identifier	REQ-PJ.11-A1-TS-STMa.0020
Title	Surveillance Report: ownship data computation
Requirement	STM shall provide the function processing Ownship Track File and computing all ownship parameters required in Surveillance Report coasted to the Surveillance report reference time.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	Appendix E, E.1
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0021
Title	Detection of coasted out track files
Requirement	STM shall provide the function iterating through all stored Target data structures and checking whether criteria for maintaining (i.e. < maximum coast time) Track Files are satisfied.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1

<SATISFIES>	<ATMS Requirement>	1440, 1441
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0022
Title	Deletion of coasted out Track Files
Requirement	STM shall delete any Track File for which the track maintaining criteria (i.e. < maximum coast time) are not satisfied.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	Algorithms 114-119[28]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0023
Title	Deletion of empty Target data structures

[28] See [34].

Requirement	STM shall delete any Target Data structure which does not contain any Track File.
Status	<Validated>
Rationale	Derived through abstraction of ADD.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier	
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1	
<SATISFIES>	<ATMS Requirement>	Algorithms 114-119[29]	
< ALLOCATED_TO >	<Enabler>	AC/54-A	
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm	
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr	
<ALLOCATED_TO>	<Resource Interaction>	N/A	

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0024
Title	Tracked data quality assessment
Requirement	STM shall provide the function that assesses the quality of information in ADS-B Track File of the given Target and whether conditions for inclusion of the Target to Surveillance Report are satisfied.
Status	<Validated>
Rationale	Derived through abstraction of ADD – implemented for ADS-B data using active validation with Mode S tracked data. The active validation is performed by analysing dedicated active validation data structure containing a limited

[29] See [34].

	history (a given number of last active measurements) of the correlated active and ADS-B state estimations (range, bearing, altitude).
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	Algorithm 120[30]
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr, 1liJctt4Tb0p
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0025
Title	Surveillance report content
Requirement	STM shall provide the function that uses the data contained in the Target data structure to decide whether given target is to be included in Surveillance Report.
Status	<Validated>
Rationale	Derived through abstraction of MOPS.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	Algorithm 97[31]
< ALLOCATED_TO >	<Enabler>	AC/54-A

[30] See [34].

[31] See [34].

<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0026
Title	Reported surveillance data generation
Requirement	Data selection logic shall prioritize ADS-B. If there is ADS-B Track File with sufficient quality and active validation is successful, ADS-B data shall be used. Otherwise, active (Mode S) Track File shall be used to generate Intruder File.
Status	<Validated>
Rationale	Derived through abstraction of ADD. It should be noted that according the ACAS X ConOps the STM should use specialized tracker/filters which “excel at combining inputs from various sources, providing a best estimate of the position and velocity of a target, and accounting for uncertainty in the input measurements and output of the filter.” Nevertheless, the current implementation of STM does not combine inputs from two types of measurements but rather select between the two surveillance information. Moreover, one ADS-B quality parameter – NACp – is reduced: despite the parameter is used as part of quality check, all ADS-B data are considered on NACp = 7 level.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 2.2.5.1.2
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0027
Title	Probabilistic state estimations
Requirement	STM shall provide the state estimation for a Target in the form of a probabilistic distribution (sigma sample): • of Target's horizontal state (relative position and velocity in North/South, East/West Cartesian coordinates) containing 9 weighted states, and • of Target's vertical state (relative altitude and vertical rate) containing 5 weighted states.
Status	<Validated>
Rationale	Derived through abstraction of ADD[32].
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	§ 2.2.5.1.3
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

[REQ]

Identifier	REQ-PJ.11-A1-TS-STMa.0034
Title	Surveillance source correlation / decorrelation.
Requirement	STM for ACAS Xa shall be able to correctly perform surveillance source correlation / decorrelation.

[32] The interface definition in ADD specifies that the Cartesian coordinates should be used. Nevertheless, TRM logic is based on the use of cylindrical coordinates and therefore this data are within TRM input processing transformed to cylindrical. Taking into account that active surveillance provides measurement directly in cylindrical coordinates, and ADS-B data needs some transformation in both cases, the possibility of using cylindrical coordinates at the STM/TRM seems to be a meaningful alternative.

Status	<Validated>
Rationale	Derived from ADD. Surveillance source correlation function is performed prior generating the STM report.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ.11-A1
<SATISFIES>	<ATMS Requirement>	2600, 2601, 2602
< ALLOCATED_TO >	<Enabler>	AC/54-A
<ALLOCATED_TO>	<Functional block>	cliJIHt4TPTm
<ALLOCATED_TO>	<Function>	tiiJ4Du4T9Hr
<ALLOCATED_TO>	<Resource Interaction>	N/A

5 Implementation Options

Not Applicable

6 Assumptions

Not Applicable

7 References and Applicable Documents

7.1 Applicable Documents

Content Integration

[1] PJ19 D5.7: EATMA Guidance Material and Report (2018)

[2] EATMA Community pages

[3] SESAR ATM Lexicon

Content Development

[4] PJ19-02 D19.2.1 SESAR 2020 Concept Of Operations Edition 2017

System and Service Development

[5] 08.01.01 D52: SWIM Foundation v2

[6] 08.01.01 D49: SWIM Compliance Framework Criteria

[7] 08.01.03 D47: ATM Information Reference Model

[8] 08.03.10 D45: ISRM Foundation Rulebook

[9] B.04.03 D102 Service Method Update 2015-Report

[10] B.04.03 D128 ADD SESAR1

[11] B.04.05 Common Services Foundation Method

Performance Management

[12] PJ19.04 D4.4: Performance Framework (2018)

[13] 16.06.06-D68 Part 1 –SESAR Cost Benefit Analysis – Integrated Model

[14] 16.06.06-D51-SESAR_1 Business Case Consolidated_Deliverable-00.01.00 and CBA

[15] Method to assess cost of European ATM improvements and technologies, EUROCONTROL (2014)

[16] Standard Inputs for EUROCONTROL Cost Benefit Analyses

[17] 16.06.06 D26 ATM CBA Quality Checklist

[18] 16.06.06 D2604 Guidelines for Producing Benefit and Impact Mechanisms

Validation

[19]03.00 D16 System Engineering Methodology for the V&VP, V&VI and Demonstration Platform development

[20]PJ19 D2.4 VALS (2018)

System Engineering

[21]SESAR 2020 Requirements and Validation Guidelines

Safety

[22]SESAR, Safety Reference Material, Edition 4.1, December 2018

[23]SESAR, Guidance to Apply the Safety Reference Material, Edition 3.1, December 2018

[24]16.01.04 D07, Final Guidance Material to execute proof of concept V2, Edition 4, August 2015

[25]16.06.01b D04, Resilience Engineering Guidance Final Deliverable, May 2016

Human Performance

[26]PJ19 HP Assessment Process for V1 to V3- including VLDs

Environment Assessment

[27]16.06.03 D27, SESAR ENV Assessment Process 4 (ERM methodology update)

[28]ICAO CAEP – "Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes" document, Doc 10031.

Security

[29]SESAR, SecRAM 2.0 Security Risk Assessment methodology for SESAR 2020

[30]SESAR, SecRAM catalogues

7.2 Reference Documents

[31]ED-78A GUIDELINES FOR APPROVAL OF THE PROVISION AND USE OF AIR TRAFFIC SERVICES SUPPORTED BY DATA COMMUNICATIONS.[33]

[32]Concept of Operations for the Airborne Collision Avoidance System X, ACAS X CONOPS, Version 2, Revision 0, April 2013

[33]Minimum Operational Performance Standard for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo) RTCA DO-385/EUROCAE ED-256, Volume I., September 2018

33

[34]Minimum Operational Performance Standard for Airborne Collision Avoidance System X (ACAS X) (ACAS Xa and ACAS Xo) RTCA DO-385/EUROCAE ED-256, Volume II: Algorithm Design Description, August 2018

[35]System Requirements Specification for Active and Operational Variants (XA/XO) of the Airborne Collision Avoidance System X, ACAS X SRS, Version 0, Revision 2, January 2014

[36]STM Technical Specifications – issue 3, SESAR 09.47, TCAS Evolution, deliverable D29, August 2016

[37]Surveillance Requirements Definition for ACAS-Xa, SESAR 09.47, TCAS Evolution, deliverable D19, April 2014

[38]STM Technical Specifications – issue 2, SESAR 09.47, TCAS Evolution, deliverable D24, September 2015

[39]SESAR Solution PJ.11-A1: Validation Report (VALR) for V3, Deliverable D3.1.060, 18 June 2019

[40]SESAR Solution PJ.11-A2: Technical Specification (TS/IRS) for V2, Deliverable D4.2.050, 14 September 2019

Appendix A Implemented STM Inputs

Mode S Active Surveillance (DF0)

Slant range to intruder

Bearing to intruder

Intruder barometric altitude

Intruder Mode S address

Intruder altitude quantization (25 or 100)

Intruder reply information (i.e., equipage)

Sensitivity Level

Surveillance Mode

Time of applicability

Mode C Active Surveillance

Array of Mode C replies derived from a single Whisper Shout sequence

ADS-B Airborne Position Report

Intruder latitude

Intruder longitude

Intruder barometric altitude

Intruder Mode S address

Intruder NIC

Intruder altitude quantization (25 or 100)

Flag to indicate message received from ADS-R

Flag to indicate that the address is a non-standard ICAO address (anonymous address)

Time of applicability

ADS-B Airborne Velocity Report

Intruder velocity in east-west direction

Intruder velocity in north-south direction

Intruder vertical velocity

Intruder Mode S address

Intruder NIC

Flag to indicate message received from ADS-R

Flag to indicate that the address is a non-standard ICAO address (anonymous address)

Time of applicability

ADS-B Mode Status Report

Intruder ADS-B version

Intruder has an operational TCAS

Intruder NACp

Intruder NACv

Intruder SIL

Intruder SDA

Intruder Mode S address

Flag to indicate message received from ADS-R

Flag to indicate that the address is a non-standard ICAO address (anonymous address)

Time of applicability

Ownship Discretes

Own Mode S address

Own Mode A address

System operational flag

Externally set sensitivity level

Flag to indicate if the display is allowed on ground

Flag to indicate whether ownship is operating on the surface or taking-off / airborne

Flag to indicate if ADS-B Only TA-Only is allowed

Flag to indicate if ownship altitude is 100 foot quantized

Flag to inhibit climb advisories

Flag to inhibit increase climb advisories

Time of applicability

Ownship input – Target Designation

Intruder Mode S address

Selected Xo Designation for Intruder

Ownship Barometric Altitude Observation

Own barometric altitude

Time of applicability

Ownship Radio Altitude Observation

Own radio altitude

Time of applicability

Ownship Heading Observation

Own heading

Time of applicability

Degraded heading mode

Ownship WGS84 Observation

Own latitude

Own longitude

Own velocity in east-west direction

Own velocity in north-south direction

Time of applicability

Ownship Input – UF16UDS30 Message

Intruder Mode S address

Cancel vertical resolution Advisory complement

Vertical resolution advisory complement

Vertical sense bits

Time of applicability

Appendix B Main STM Data Structure

B.1 STM Output Data Structures

STM Report data structure produced by the STM, partly consumed by the TRM to perform threat evaluation, contains:

Exact input to the TRM
Data to be processed by the transponder (ownship)
Data to be sent to the pilot display (intruder)

STM Display data structure contains intruder state data that is provided to the display and is part of STM Report. The structure itself contains:

Vertical rate arrow for the display
Indication that intruder is reporting altitude
Intruder ID
Relative altitude
Tracked ground range
Bearing relative to own airframe
Intruder Mode S address
Indication whether intruder address is ICAO compliant
Validity flag for Xo CSPO-3000 designation
Validity flag for Xo DTA-ONLY designation
The pending state for Xo CSPO-3000 designation
The pending state for Xo DTA-ONLY designation

Transponder data structure contains:
Ownship air to air reply information
Ownship sensitivity level
Ownship transponder version indicator
Data link subfield bits (48, 69, 70, 71, and 72)

B.2 STM Internal Data Structures

Active Validation History data structure contains two Range Altitude data structures that represent a history of estimates from an active and a passive track:

Range Altitude (active)
Range Altitude (passive)

ADS-B Track File data structure contains two tracks, one for vertical dimension and one for the horizontal dimension. Each track has their own time of applicability.

reported Mode S Address

intruder address is non-ICAO flag

track file is ADS-R flag

number of position updates

the presence and operational status of TCAS reported by TCAS Operational field

mean of ADSB Track (four values: relative position and velocity in the east/west, north/south)

covariance of ADSB Track (matrix 4x4)

outlier detection count for ADSB Track

boolean determining if the velocity is already initialized

mean of Vertical Track (relative altitude and vertical rate)

covariance of Vertical Track (matrix 2x2)

outlier detection count for Vertical Track

the number of Vertical track updates

validity flag for the Vertical Track

the altitude quantization level

ADS-B version

navigation integrity category (NIC)

the accuracy of the reported position (NACp)

the accuracy of the reported velocity (NACv)

surveillance integrity level (SIL)

system design assurance (SDA)

Track summary data structure used in correlation

time of applicability for horizontal tracker

time of applicability for vertical tracker

time of applicability – last ADS-B position update

time of applicability – track file

current vertical rate arrow on display

previous vertical rate arrows sent to display

ownship latitude, longitude and baro. altitude at time of horizontal toa

ownship ECEF 3-D position at time of horizontal toa

Correlation History data structure contains:

Timing interval when the tracks correlated/decorrelated

IDs of the two tracks as an array of pairs

Designation State contains state information associated with target designation. There is one Designation State structure for each Target. The data structure is following:

Mode S address

Indication of validity/invalidity for Xo DTA-ONLY or CSPO-3000

Current Xo Designated No Alerts state (set by TRM)

Current protection mode (Xa, Xo, CSPO-3000, also set by TRM)

Pending Xo Designated No Alerts state (set by TRM)

Pending protection mode (Xa, Xo, CSPO-3000, set by STM)

Timer for invalid timeout for Xo Designated No Alerts

Timer for invalid timeout for Xo protection mode

Flag to indicate target is in use: don't delete target if all tracks are lost

Flag to inhibit output to TRM for processing and STM display output

Designation setting for output

Status to be published to ASA processor

Flag to indicate if RA is active on the target

Flag to indicate if this target is part of multithread RA

Flag indicating whether target is currently designated

Flag to indicate the radar altimeter is inactive (NaN) or the radar altimeter reading is above the upper aural inhibit threshold

Flag to indicate the radar altimeter is active (not NaN) and its reading is below the lower aural inhibit threshold

Proximity indication

Recent history of distances to target while designated

Hypothetical Mode C Track File data structure contains:

Array of Mode C replies derived from single Whisper Shout sequence

Measured range rate

Measured range

Altitude

Relative bearing

Time of applicability

Track file age

ModeCReply data structure contains:

External ID (optional)

Reported altitude code (decoded using Gillham Gray code)

Altitude confidence bits

Measured slant range

Relative bearing

Time of applicability associated with a single reply from a Mode C transponder.

ModeCTrackFile data structure includes three tracks, one for the vertical dimension, and two for horizontal dimension. Each track has their own time of applicability. Data structure contains:

Mean of Cartesian track

Covariance of Cartesian Track (matrix 4x4)

Outlier detection count for Cartesian Track

The number of Cartesian track updates

Validity flag for the Cartesian Track

Mean of Range Track (relative range, range rate, and acceleration)

Covariance of Range Track (matrix 3x3)

Outlier detection count for Range Track

The number of Range track updates

Validity flag for the Range Track

Mean of Vertical Track (relative altitude and vertical rate)

Covariance of Vertical Track (matrix 2x2)

Outlier detection count for Vertical Track

The number of Vertical track updates

Validity flag for the Vertical Track

The altitude quantization level

The reported sensitivity level

Flag indicating if it is an image track

Track summary

Previous range observation

Flag to indicate range track is coasting

Flag to indicate altitude is not available

Time of applicability for vertical tracker

Time of applicability for Cartesian tracker

Time of applicability for range tracker

Time of applicability – track file

Current vertical rate arrow on display

Previous vertical rate arrows sent to display

Flag to indicate target is on ground

Data structure used in on-ground determination

Mode S Track File data structure includes three tracks, one for the vertical dimension and two for the horizontal dimension. Each track has their own time of applicability. Data structure contains:

reported Mode S Address

Intruder reply information (i.e. equipage)

Flag to indicate altitude is not available

the presence and operational status of TCAS reported by RI field

mean of Cartesian Track (four values: relative position and velocity in east/west, north/south)

covariance of Cartesian Track (matrix 4x4)

outlier detection count for Cartesian Track

the number of Cartesian track updates

validity flag for the Cartesian Track

mean of Range Track (relative range, range rate, and acceleration) covariance of Range Track (matrix 3x3)

outlier detection count for Range Track

the number of Range track updates

validity flag for the Range Track

mean of Vertical Track (relative range and range rate)

covariance of Vertical Track (matrix 2x2)

outlier detection count for Vertical Track

the number of Vertical track updates

validity flag for the Vertical Track

the altitude quantization level

current surveillance region

track summary

previous range observation

Flag indicting range track coasting

time of applicability for vertical tracker

time of applicability for Cartesian tracker

time of applicability for range tracker

time of applicability – track file

Current vertical rate arrow on display

Previous vertical rate arrows sent to display

OwnDiscreteData data structure includes:

Own Mode S address

Own Mode A code

Flag to indicate whether the system is operational

Manually selected sensitivity level

Flag to indicate if the display is allowed on the ground

Flag to indicate that aircraft is operating on surface

Flag to indicate that TAs against ADS-B only intruders are enabled

Flag to indicate if ownship altitude is 100 foot quantized

OwnShipData structure:

the ownship Mode S Address

the ownship radio altitude

the mean and covariance of ownship heading and heading rate

time of applicability of ownship heading

ownship heading initialized

ownship heading track state

ownship heading track outlier detection count

the mean and covariance of ownship altitude and altitude rate

time of applicability of ownship altitude

ownship latitude

ownship longitude

ownship east/west velocity

ownship north/south velocity

wgs84 time of applicability

ownship WGS84 previous report time of applicability

Information related to advisory modes (TA only mode, TA/RA mode)

ownship sensitivity level

Indicated if ownship is on the ground

Number of invalid radio altitude measurements

The threat resolution advisory complement array

Target independent correlation history

Target independent decorrelation history

Data structure of discrete inputs

Data structure of transponder outputs

OwnHistory data structure contains a history of bearing and barometric ownship altitude measurements:

own heading observation

own barometric observation

VertHistory data structure contains a history of the vertical dimensions of both received observations and track estimates.

RangeAltitude data structure contains two arrays which represent a history of range and altitude estimates (used for purpose of active validation).

ReceivedCoordinationData structure contains coordination data from a target:

Vertical Resolution Advisory Complement (VRC)

Time of applicability

Target data structure represents all data related to a single physical aircraft that is under surveillance by ACAS X:

Array of Mode S Track Files

Array of ADS-B Track Files

Array of ADS-R Track Files

Array of Mode C Track Files

Received Coordination Data

bad_uf16uds30

Active Validation History information

State of active validation

ADS-B quality history information

Flag to override the ADS-B quality check used for Hybrid Surveillance targets

Target designation state

Time of initialization

Indication that a collision avoidance system is operational

Indication of CAS and type capability

Detect and Avoid subfield that indicates the coordination type to be provided

Database acts as a wrapper around the Julia Dictionary type with the addition of an increment field.

TrackMap associates Track File with ID in the Target Database. Data structure includes:

Track file

Database ID

TrackSummary contains three tracks, one for vertical dimension and two for horizontal dimension. Data structure includes:

Time of applicability

Mean and covariance for vertical, Cartesian and range trackers

ValueTime pair stores arrays of specified values with associated times.

LastUpdateRng contains:

Slant range to target

Relative altitude of target

Barometric altitude

Time of Applicability

Flag indicating invalid measurement

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