TCAS RA Display to Controllers

A Belgocontrol Study

Belgocontrol

May 2017

Table of Contents

1 Definitions, acronyms and abbreviation(s)

ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre or Area Control
ACP	Area Control Procedural (*license*)
ACS	Area Control Surveillance (*license*)
AIP	Aeronautical Information Publication
ANSP	Air Navigation Service Provider
APP	Approach Control Centre or Approach Control
APP *license*	Approach Control Procedural *license*
APS	Approach Control Surveillance (*license*)
APW	Area Proximity Warning
ARTAS	ATM surveillance Tracker And Server
ATC	Air Traffic Control
ATCO	Air Traffic Controller or Air Traffic Control Officer
ATM	Air Traffic Management
ATS	Air Traffic Services
BCAA	Belgian Civil Aviation Authority
BGATC	Belgian Guild of Air Traffic Controllers
BSA	Belgian Supervisory Authority
C/S	CallSign
CA	Conflict Alert
CAA	Civil Aviation Authority or Civil Aeronautics Authority
CANAC	Computer Assisted National Air Traffic Control Center
CFL	Cleared Flight Level
CPA	Closest Point of Approach
CWP	Controller Working Position
CSSA	Changed System Safety Assessment
DAP	Downlink Aircraft Parameter
DF	Direction Finder
DFS	Deutsche Flug Sicherheitz dienst (German ANSP)
DGO	Directorate General Operations
DGS	Directorate General Systems
DSA	Downlinked Selected Altitude
DSS	Data System Specialist
E-E	EUROCAT-E system (provided by Thales)
EBBR	ICAO Airport Designator of Brussel
EBBU	ICAO Location Indicator of Brussels Control Centre
ELS	Mode S Elementary Surveillance
EHS	Mode S Enhanced Surveillance
EU	European Union
FL	Flight Level
HMI	Human Machine Interface
HPPQ	High Priority Personal Queue

HVR	High Vertical Rate
ICAO	International Civil Aviation Organization
IFATCA	International Federation of Air Traffic Controllers'ASSNS
OCA	Operational Competence Assessment or Operational Competence Assessor
OSU	Operational Safety Unit
MATS	Manual of Air Traffic Services
MRTS	Multi-Radar Tracking System
MSAW	Minimum Safe Altitude Warning
MTCD	Medium Term Conflict Detection
N/A	Not Applicable or Not Available or Not Assigned
Ntc	Note to Controller
N2Ops	Note to Operations (electronic version of Ntc)
OJT	On the Job Training
OJTI	On the Job Training Instructor
RA	Resolution Advisory
SESAR	Single European Sky ATM Research
SMS	Safety Management System
SMU	Safety Management Unit
SSR	Secondary Surveillance Radar (code)
STCA	Short Term Conflict Alert
TC	Training Centre
TCAS	Traffic Collision Avoidance System
TOF	Training Officer
WP	Working Position

2 Introduction

Resolution Advisories (RAs) are issued to the pilots by the Airborne Collision Avoidance System (ACAS) (also referred to as TCAS - Traffic alert and Collision Avoidance System) if a risk of collision is identified. The RA takes precedence over ATC instructions and the controller should not interfere with the resulting collision avoidance manoeuvre.

Typically, controllers only know about RAs when, and if, pilots report them. If an aircraft departs from its clearance as the result of an RA and the pilot does not promptly report this, the controllers' situational awareness may diminish and they may unknowingly provide a contradictory instruction.

To counter this, RA Downlink has been developed which transmits RA information to the ground via different channels.

This document provides information on the relevance and applicability of RA Downlink based on examination of ACAS, Mode S communication, the legal aspects of ACAS and pilots and controller responsibilities, best practices by stakeholders, and other studies to date.

3 RA Downlink

The Überlingen accident investigation report made the following recommendation: “To enhance the performance of ACAS ICAO should initiate the development of down-linking RAs to ATC, using such technologies as SSR Mode S and Automatic Dependent Surveillance Broadcast (ADS-B)”.[1]

The concept of displaying ACAS RA-Alerts to the Controller Working Position was developed after it became apparent that pilots often tend to report on-going ACAS Resolution Advisories late, too late or even not at all.

A particular safety-critical event is the execution of opposite direction (or sense) manoeuvres to the ACAS RA. As the existence of an ACAS RA has a tremendous effect on the separation responsibility of ATCOs and as well on the ATC-clearances that could be issued during an ACAS RA-manoeuvre, this all can have significant effects on the aviation safety (especially immediate ATC-instructions issued unknowingly against the sense of the ACAS RA), the full awareness of the ATCO about the on-going ACAS RA and its associated manoeuvres is essential to aviation safety.[2]

The RA Downlink is technically possible according to the FARADS study. Within the Mode-S coverage area Mode-S RA reports are the best solution. The Mode-S RA reports are already specified in ICAO Annex 10[3](see {FARADS}).

4 Information on TCAS

Traffic alert and Collision Avoidance System (TCAS) is the only commercially available implementation of the ICAO standard for ACAS II.

---

[1] {HS22} pg24 and {FARADS}
[2] {SES_IVT}{SES_IVT}
[3] {ANNEX10}

Airborne collision avoidance system (ACAS) is an aircraft system based on secondary surveillance radar (SSR) transponder signals which operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft that are equipped with SSR transponders.

There are two types of ACAS:

1. ACAS I issuing only Traffic Advisories (TAs)
2. ACAS II issuing Resolution Advisories (RAs), in addition to TAs, in the vertical plane only.

An ACAS III concept issuing RA in the vertical and horizontal plane exist but it will not be developed. A new collision avoidance system, ACAS X, is in development.

4.1 Objectives of ACAS[4]

The objective of ACAS is to provide advice to pilots for the purpose of avoiding potential collisions. This is achieved through resolution advisories (RAs), which recommend actions (including manoeuvres), and through traffic advisories (TAs), which are intended to prompt visual acquisition and to act as a precursor to RAs.

ACAS has been designed to provide a back-up collision avoidance service for the existing conventional air traffic control (ATC) system while minimizing unwanted alarms in encounters for which the collision risk does not warrant escape manoeuvres. The operation of ACAS is not dependent upon any ground-based systems.

4.2 System overview[5]

ACAS equipment in the aircraft interrogates Mode A/C and Mode S transponders on aircraft in its vicinity (on the 1030 MHZ ‘challenge’ frequency) and listens for their replies (on the 1090 MHZ ‘reply’ frequency). By processing these replies, ACAS determines which aircraft represent potential collision threats and provides appropriate display indications (or advisories) to the flight crew to avoid collisions.

ACAS equipment is capable of providing two classes of advisories:

1. TA – Traffic Advisory or Traffic Alert: warning the pilot of the presence of another aircraft that may become a threat, i.e. aircraft that may later cause RAs to be displayed. TAs indicate the position of the intruding aircraft relative to own aircraft. TAs without altitude information are also provided against non-altitude-reporting, transponder-equipped aircraft.
2. RA – Resolution Advisory: alert providing information to pilots on how to modify or regulate their vertical speed to avoid a potential mid-air collision. The sense (direction) of RAs is coordinated between ACAS equipped aircraft.

The RA may be preventive or corrective:[6]

---

[4] From {DOC9863}
[5] Combination of text from {DOC9863} & {ACASII}
[6] {SSR_ACAS}

1. Preventive RA: A Resolution Advisory giving a manoeuvre restriction intended to maintain existing separation
2. Corrective RA: A Resolution Advisory instructing a manoeuvre intended to provide separation from all threats

4.3 ACAS operation[7]

ACAS equipment periodically transmits interrogation signals. These interrogations are replied to by transponders installed on nearby aircraft. A Mode C transponder replies with its altitude. A Mode S transponder replies with its altitude and unique aircraft address.[8] ACAS does not use Mode A interrogations, therefore the Mode A transponder code of nearby aircraft are not known to ACAS.

ACAS then computes the range of the intruding aircraft by using the round-trip time between the transmission of the interrogation and the receipt of the reply. Altitude, range and bearing (using a directional antenna) are estimated from the reply information and used to determine whether the intruding aircraft is a threat.

If the threat detection logic in the ACAS computer determines that a nearby aircraft represents a potential, imminent collision, the computer threat resolution logic determines the appropriate vertical manoeuvre or vertical manoeuvre restriction to reduce the risk of collision. Each threat aircraft is processed individually to permit selection of an RA based on track data. The appropriate manoeuvre is one that avoids all threat aircraft, assuming that the threat aircraft do not manoeuvre to thwart the RA and that own aircraft complies with the RA.

If a threat aircraft is equipped with ACAS that is capable of generating RAs, a coordination procedure via the air-to-air Mode S data link is performed. This procedure assures that the RAs are compatible. TAs are intended to alert the flight crew to the presence of potential threat aircraft with a longer warning time than that provided by RAs.

ACAS thresholds are independent from ATC separation standards because ACAS does not strive to ensure separation (which is ATC's role) but tries to avoid collision as a last resort. The main ACAS thresholds are time-based, not distance-based like most ATC separation standards. In any potential collision, ACAS generates an RA nominally 15 to 35 s before the closest point of approach (CPA) of the aircraft. The ACAS equipment may generate a TA up to 20 s in advance of an RA. Warning times depend on sensitivity levels (SLs) of RAs.

[7] {DOC9863}
[8] Transponder-equipped aircraft may temporarily not report altitude, but will reply

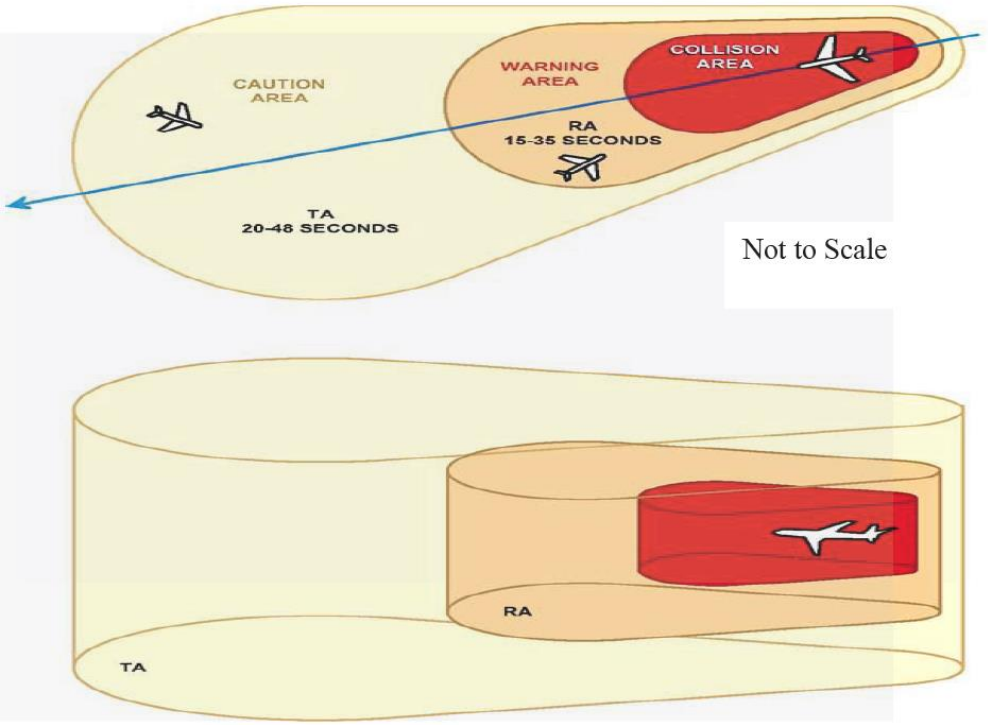


Figure 1 TCAS protection areas

4.4 System components[9]

The equipped aircraft carries ACAS surveillance electronics that interrogates and receives replies from Mode S and Mode A/C transponders on other aircraft. The components of ACAS are shown in the figure below:

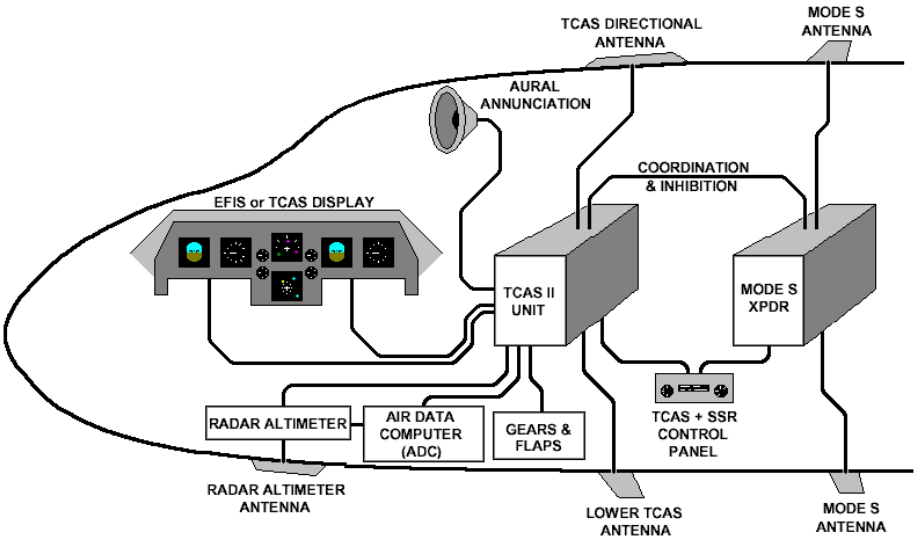


Figure 2: ACAS components

[9] {DOC9863} + {ACASII}

The ACAS-equipped aircraft also carries a Mode S transponder that performs the functions of existing Mode A/C transponders and provides Mode S air-to-air communications for coordinating the resolution of encounters between ACAS-equipped aircraft. The Mode S transponder may also be used for communications with a ground-based Mode S sensor for surveillance and data link purposes (DAP downlink).
TCASII always utilises pressure altitude information which relates to the standard pressure (altimeter settings 1013.25 hPa). Additionally, below 1750ft, ACAS also uses radio altimeter data.

4.5 Design intention of ACASII[10]

ACAS II was designed for use on turbine-powered, fixed-wing aircraft flying in accordance with civil operating procedures. ACAS II was not designed for use by closely spaced formation aircraft, rotary wing aircraft or aircraft operating in clusters; with the intent of being installed on tactical military (e.g. fighter aircraft) or unmanned aircraft. As such, there are technical and· operational issues that must be addressed and resolved prior to installing ACAS II on these types of aircraft.

4.6 Collision avoidance and ACAS[11]

1) TAs can be issued against any transponder-equipped aircraft that responds to the ICAO Mode C interrogations, even if the aircraft does not have altitude-reporting capability;
2) RAs can be issued only against aircraft that are reporting altitude and in the vertical plane only;
3) RAs issued against an ACAS-equipped intruder are coordinated to ensure that complementary RAs are issued;[12]
4) failure to respond to an RA deprives the aircraft of the collision protection provided by its ACAS. Additionally, in ACAS-ACAS encounters, it also restricts the choices available to the other aircraft's ACAS and thus renders the other aircraft's ACAS less effective than if the first aircraft were not ACAS-equipped; and
5) manoeuvring in a direction opposite to that indicated by an RA is likely to result in further reduction in separation. This is particularly true in the case of an ACAS-ACAS coordinated encounter.

4.7 ACAS capabilities, limitations and inhibits [13]

Capabilities

ACAS has the ability to modify the initially issued RA as the encounter geometry changes or if the response to the RA results in another aircraft becoming a threat. The modified RAs can call for a weakening of the initial RA to minimize clearance deviations once the ACAS-desired vertical miss distance is obtained, or there has been an increase in vertical speed or a reversal of the direction of the initial RA.

---

[10] {DOC9863}
[11] {DOC9863}
[12] Coordinated RAs are only performed between two ACAS II equipped aircraft. ACAS I operations cannot be coordinated with ACAS II.
[13] {DOC9863} & {DOC8168}

In some encounter geometries, ACAS will issue an RA that requires the ACAS-equipped aircraft to cross through the intruder aircraft's altitude. This manoeuvre is selected only when the non-altitude crossing RA will not provide the desired separation.

ACAS will track multiple aircraft and if two or more intruders meet the criteria for the issuance of an RA simultaneously, the RA issued will provide separation from all intruders.

Current systems may display targets to the pilot at long ranges, e.g. 56--74 km (30-40 NM). However, reliable ACAS surveillance is only guaranteed out to 26 km (14 NM) in en-route airspace with low traffic density. As traffic density increases, reliable ACAS surveillance progressively diminishes to a guaranteed minimum of 8.3 km (4.5 NM).

The response to an RA can result in a loss of standard ATC separation with either the aircraft causing the RA or a third aircraft. If the third aircraft becomes a threat while the RA is still displayed, the RA will be modified to provide the ACAS-desired vertical miss distance from both aircraft. However, because of the differences in the RA thresholds and ATC separation standards, the modification to the RA is likely to occur after ATC separation is lost.

ACAS can detect and discard short-term, spurious errors in Mode C replies. However, no techniques exist that allow it to detect a constant bias error or offset. Thus, ACAS will accept Mode C replies that are erroneous and it is possible to issue an RA based on these inputs. PANS-ATM contains procedures that permit a controller to request that the altitude reporting function of the transponder be disabled. To prevent RAs caused by erroneous Mode C reports, it is essential that this procedure be implemented and followed. Controller training programmes should emphasize the danger of allowing erroneous Mode C reports to continue. In view of the 150 m (500 ft) separation between VFR and IFR aircraft in some States, it is recommended that the tolerance for requesting the discontinuance of altitude reporting be reduced from 90 m (300 ft) to 60 m (200 ft).

Limitations

a) ACAS will neither detect, track, nor display and issue advisories against non-transponder-equipped aircraft, nor aircraft with an inoperable transponder, nor aircraft with a Mode A transponder;
b) ACAS will issue TAs against altitude reporting and non-altitude reporting intruders but will not issue RAs against non-altitude reporting intruders.
c) ACAS will automatically fail if the input from the aircraft’s barometric altimeter, radio altimeter, or transponder is lost;
d) some aircraft within 116 m (380 ft) above ground level (AGL) (nominal value) will not be displayed. If ACAS is able to determine that an aircraft below this altitude is airborne, it will be displayed;
e) ACAS may not display all proximate transponder-equipped aircraft in areas of high-density traffic; however, it will still issue RAs as necessary;
f) because of design limitations, the bearing displayed by ACAS is not sufficiently accurate to support the initiation of horizontal manoeuvres based solely on the traffic display;
g) because of design limitations, ACAS will neither display nor give alerts against intruders with a vertical speed in excess of 3 048 m/min (10 000 ft/min). In addition, the design implementation may result in some short-term errors in the tracked vertical speed of an intruder during periods of high vertical acceleration by the intruder; and
h) stall warnings, ground proximity warning system (GPWS) warnings and wind shear warnings take precedence over ACAS advisories. When either a GPWS or wind shear warning is active, ACAS will automatically switch to the TA-only mode of operation

except that ACAS aural annunciations will be inhibited. ACAS will remain in TA-only mode for 10 seconds after the GPWS or wind shear warning is removed.

Levels of protections

Threat aircraft equipment	Own aircraft (TCAS II)
No transponder	Not detected
Mode A transponder only	Not detected
Mode A/C transponder with no altitude reports	TA, intruder shown on TCAS traffic display without altitude
Mode C or Mode S transponder	TA and RA
TCAS I	TA and RA
TCAS II	TA and coordinated RA

ACAS inhibits

a) increase descent RAs are inhibited below 442 (±30) m (1 450 (±100) ft) AGL;
b) descend RAs are inhibited below 335 (±30) m (1 100 (±100) ft) AGL;
c) all RAs are inhibited below 305 (±30) m (1 000 (±100) ft) AGL;
d) all ACAS aural annunciations are inhibited below 152 (±30) m (500 (±100) ft) AGL. This includes the aural annunciation for TAs; and
e) altitude and configuration under which climb and increase climb RAs are inhibited. ACAS can still issue climb and increase climb RAs when operating at the aircraft=s maximum altitude or certified ceiling. However, if aeroplane performance at maximum altitude is not sufficient to enable compliance with the climb rate required by a climb RA, the response should still be in the required sense but not beyond the extent permitted by aeroplane performance limitations.

4.8 TCAS versions[14]

At the time of the survey, two versions of TCAS were available: version 7.0 and version 7.1. The tables below describes the differences.

Pilot RA aural alerts TCAS II version 7.0

Upward sense			Downward sense		
RA	Required vertical rate (ft/min)	Aural	RA	Required vertical rate (ft/min)	Aural
Climb	1500	Climb, climb	Descend	- 1500	Descend, descend
Crossing Climb	1500	Climb, crossing climb; Climb, crossing climb	Crossing Descent	- 1500	Descend, crossing descend; Descend, crossing descend
Maintain Climb	1500 to 4400	Maintain vertical speed, maintain	Maintain Descent	- 1500 to - 4400	Maintain vertical speed, maintain
Maintain Crossing Climb	1500 to 4400	Maintain vertical speed, crossing maintain	Maintain Crossing Descent	- 1500 to - 4400	Maintain vertical speed, crossing maintain
Reduce Descent 1	0 - 500 - 1000 - 2000	Adjust vertical speed, adjust	Reduce Climb 1	0 500 1000 2000	Adjust vertical speed, adjust
Reversal Climb 2	1500	Climb, climb NOW; Climb, climb NOW	Reversal Descent 2	- 1500	Descend, descend NOW; Descend, descend NOW
Increase Climb 2	2500	Increase climb, increase climb	Increase Descent 2	- 2500	Increase descent, increase descent
Preventive RA	No change	Monitor vertical speed	Preventive RA	No change	Monitor vertical speed
RA Removed	—	Clear of conflict	RA Removed	—	Clear of conflict

1 Replaced by "Level off, level off" in version 7.1
2 Not possible as an initial RA

Pilot RA aural alerts TCAS II version 7.1

Upward sense			Downward sense		
RA	Required vertical rate (ft/min)	Aural	RA	Required vertical rate (ft/min)	Aural
Climb	1500	Climb, climb	Descend	- 1500	Descend, descend
Crossing Climb	1500	Climb, crossing climb; Climb, crossing climb	Crossing Descent	- 1500	Descend, crossing descend; Descend, crossing descend
Maintain Climb	1500 to 4400	Maintain vertical speed, maintain	Maintain Descent	- 1500 to - 4400	Maintain vertical speed, maintain
Maintain Crossing Climb	1500 to 4400	Maintain vertical speed, crossing maintain	Maintain Crossing Descent	- 1500 to - 4400	Maintain vertical speed, crossing maintain
Level Off 1	0	Level off, level off	Level Off 1	0	Level off, level off
Reversal Climb 2	1500	Climb, climb NOW; Climb, climb NOW	Reversal Descent 2	- 1500	Descend, descend NOW; Descend, descend NOW
Increase Climb 2	2500	Increase climb, increase climb	Increase Descent 2	- 2500	Increase descent, increase descent
Preventive RA	No change	Monitor vertical speed	Preventive RA	No change	Monitor vertical speed
RA Removed	—	Clear of conflict	RA Removed	—	Clear of conflict

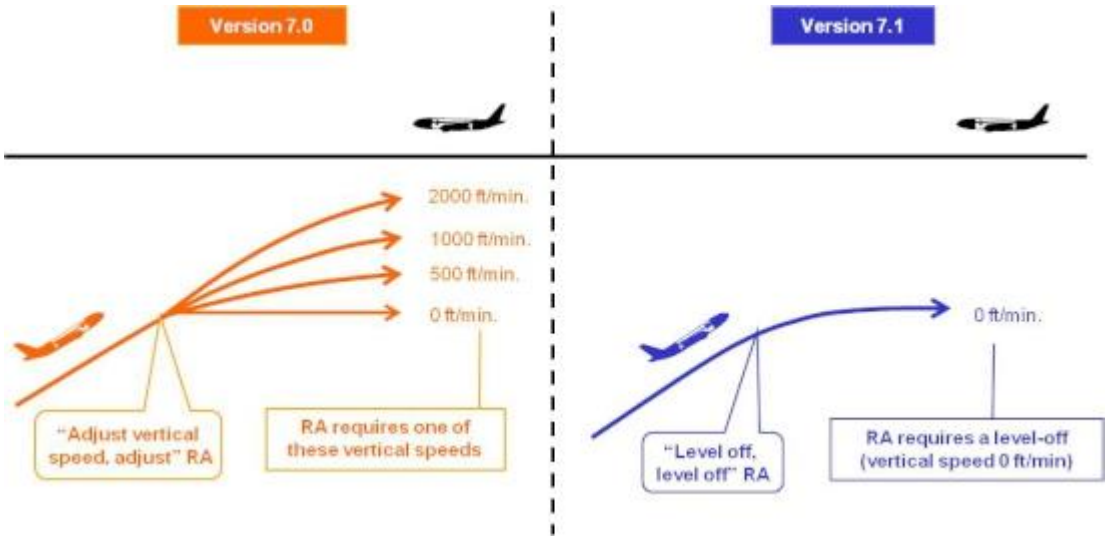
1 New RA in version 7.1, replacing "Adjust vertical speed, adjust" from version 7.0
2 Not possible as an initial RA

The main change between the two versions are:

1. An improved reversal logic

[14] {ACASII}

2. the replacement of the "adjust vertical speed" from version 7.0 by "level of" in the version 7.1; to solve the safety issue of unintentional opposite pilot response to "adjust vertical speed" RAs



4.9 TCAS and STCA[15]

STCA and TCAS were developed independently by different organisations. Whilst TCAS was and is subject to rigorous standardisation and certification, STCA was not.

The independent operation of STCA and TCAS is an important characteristic. It provides redundancy and minimises single points of failure, but at the same time it results in differences that in turn cause some incompatibilities (see table below). These incompatibilities mean that the combined behaviour of STCA and TCAS is not always predictable and well understood.

	STCA	TCAS
Performances	Ground-based surveillance has a 5 to 10 second update rate and good azimuth resolution	TCAS surveillance function has a 1 second update rate and poor azimuth resolution
Operation	STCA detects imminent or actual (significant) loss of minimum separation but provides no resolution advice	TCAS assumes collision and provides resolution advice to ensure sufficient vertical separation at the CPA
Predictability	STCA is not standardised but optimised for the operational environment to varying degrees	TCAS is fully standardised
Communication	Complete by providing instructions subject to read-back/hear-back	Limited (pilot reporting not always possible in a timely manner)
Effectiveness	Only when the controller immediately assesses the situation, issues an appropriate instruction to the pilot and the pilot follows the instruction	Only when pilot promptly and correctly follows the RA

[15] {NetAlert}

As consequence of these incompatibilities, whilst the desired behaviour is that STCA alerts at least 30 seconds before the first TCAS RA, STCA can and sometimes will trigger significantly later (sometimes even after the RA).

5 General information on Mode S SSR[16]

Secondary Surveillance Radar (SSR) Mode Select (Mode S) is a co-operative surveillance and communication system for Air Traffic Control (ATC) purposes. It employs ground-based interrogators and airborne transponders. Furthermore, ground-air-ground data link communications can be accommodated integrally with surveillance interrogations and replies. Mode S has been designed as an evolutionary improvement to the existing 'classical' SSR system operating in Modes 3A and C, and it provides the necessary improved surveillance, communication capability and capacity required to handle the forecast increased levels in air traffic. Both ground and airborne Mode S installations are backwards compatible in that Mode S interrogators will provide surveillance of aircraft equipped with Mode S and Mode 3A/C transponders and Mode S transponders will reply to existing SSR Mode 3A/C and Mode S interrogations. Mode S and Mode 3A/C interrogations are all made on 1030 MHz and all replies are made on 1090 MHz.

5.1 Principles of Mode S Operation

Aircraft Addressing. A principal feature of Mode S is that each aircraft is assigned an individual and unique identification number. This is known as an ICAO 24-bit Aircraft Address (AA), which is preset and cannot be changed from the cockpit. Although bound to the individual airframe identity, it has no direct relationship to the operational aircraft identification (i.e. callsign used in flight), other than during a specific flight. For the same reason that aircraft identification, and not the airframe identity, is used as the primary Air Traffic Management (ATM) reference, except in specific circumstances where the two are the same, the ICAO 24-bit AA will not be exposed to, or used by, operational ATC staff. Using this unique address, interrogations can be directed selectively to a particular aircraft and replies identified unambiguously. Channel interference is minimized because a radar can limit its interrogations to targets of interest. In addition, by proper timing of interrogations, replies from closely spaced aircraft can be received without mutual interference. The unique address in each interrogation and reply also permits the inclusion of data link messages to or from particular aircraft. There are nearly 17 million AAs available for use worldwide and the first few digits of each address identify the country of registration or origin.

Interrogator Codes. Another key feature of Mode S is the use of Interrogator Codes (ICs) to uniquely identify Mode S radars. The ICs comprise 15 Interrogator Identifier (II) and 63 Surveillance Identifier (SI) codes. The purpose of the ICs is to allow for unambiguous data exchange between radars and aircraft transponders. Unlike 'classical' SSR sensors, a Mode S radar has two methods of interrogating aircraft transponders: a general 'All Call' and a selective 'Roll Call'. An 'All-Call' request is used by a Mode S radar to acquire Mode S equipped aircraft entering its area of radar coverage, which will reply with their unique ICAO 24-bit AAs. After acquisition of an aircraft's ICAO 24-bit AA has been achieved, 'lock-out' protocols can then be used (based on the IC that the radar is using) to suppress further replies from the aircraft to any 'All-Call' requests by the same interrogator. The

[16] From {CAA-PA}

aircraft transponder will, however, continue to reply to 'All Call' requests from other Mode S radars using different ICs until they also apply 'lock out'; they will also continue to reply to 'classical' SSR interrogations. In effect, the ICs identify the Mode S radars to which the transponders should reply or ignore. Following an 'All-Call lock-out' by a particular Mode S radar, that radar will then selectively address an aircraft transponder using a 'Roll-Call' interrogation. Only the specifically addressed aircraft will reply and this is commonly referred to as the 'Mode S period'. The use of ICs also allows radars to discard replies that are not intended for them. It is this implementation of the 'All-Call lock-out protocols' and the 'Roll-Call' interrogations that reduces RF pollution and the problems associated with an interference phenomenon known as FRUIT (False Replies Unsynchronized In Time) and the general levels of over interrogation.

5.2 Mode S Surveillance Functionality

Elementary Surveillance. Mode S Elementary Surveillance (ELS) is the minimum surveillance functionality foreseen for aircraft equipped with any type of Mode S transponder. For Mode S ELS, the following information is provided by a transponder:

a. **Range and Azimuth**. Range and azimuth measurement is made from a single reply to a selective addressed interrogation. Position information will be of a similar accuracy to monopulse 'classical' SSR but it will not suffer from the same plot resolution problems when aircraft are very close together.

b. **Mode A and Mode C Decodes**. The routine selective addressed interrogation that is made each scan will request pressure-altitude information from an aircraft transponder. The same information is available as with the present Mode C but with a capability to decode altitudes to 25 ft precision. Selective addressed interrogations are also used to obtain Mode A 'identity' codes. Mode A information need not be requested on every scan as there is a 'bit set' in the 'Roll-Call' reply from the aircraft to highlight when its Mode A code has changed. Therefore, the Mode A code will only be requested when the aircraft is first acquired, re-acquired or when the Mode A code value is changed. This differs from existing systems when the Mode A code is requested from all aircraft within coverage on every scan.

c. **ICAO 24-bit AA**. Mode S ELS provides the ICAO 24-bit AA to enable discrete identification of the aircraft by the interrogating radar system.

d. **Aircraft Identification**. In addition to the Mode A code, an aircraft identification is provided in the form of a Downlinked Aircraft Parameter (DAP). This is an alpha-numeric string set that the flight crew are required to set on the transponder for transmission to correspond with the aircraft identification specified in Item 7 of the ICAO Flight Plan. If no Flight Plan has been filed, the transponder is required to report the aircraft registration. This information is displayed to air traffic controllers and will form the primary means of identifying flights on controller workstations.

e. **Transponder Capability**. The Transponder Capability Report is, in effect, a 'Data Link Capability Report'. Its purpose is to indicate to the radar the ability of the aircraft transponder to handle additional Mode S data link functionality. It is extracted when the aircraft is first acquired and is transmitted in the form of a DAP.

f. **Flight Status**. The Flight Status functionality will indicate whether the aircraft is airborne or on the ground and could also be used to notify emergency conditions. The Flight Status report includes the 'Squawk Ident' function and takes the form of a DAP.

Enhanced Surveillance. Mode S Enhanced Surveillance (EHS) provides all the functionality of ELS but, in addition, it provides data link functionality and access to additional DAPs. In order to achieve this, the aircraft must have an interface between the transponder and its avionics system. It is, therefore, generally only supported by aircraft with modern 'digital' avionics and is most useful to the ATC community in the busy terminal and en-route environments. The additional DAPs available are divided into the following 2 categories:

a. **Aircraft Current State Vector Information**. The aircraft current state vector information indicates the current state of motion of the aircraft. The information available can include:

(i) Ground Speed.
(ii) Track Angle.
(iii) Turn Rate.
(iv) Roll Angle.
(v) Climb Rate.
(vi) Magnetic Heading.
(vii) Indicated Air Speed.
(viii) Mach No.

b. **Aircraft Intention Information**. Aircraft intention information may be available from the avionics to indicate the future path of the aircraft. This information may be displayed to controllers and used to enhance safety net systems such as 'Short Term Conflict Alert (STCA)'. The information available includes Selected Altitude and the Barometric Pressure Setting on which this is based; this is useful for helping controllers to notice and prevent potential 'level busts' by aircraft.

5.3 Additional Mode S Functionality

Controller Access Parameters (CAPs). CAPs are those DAPs that are available for display to air traffic controllers. These CAPs will typically include magnetic heading, indicated airspeed and selected altitude.

System Access Parameters (SAPs). SAPs are those DAPs that are available to ATC systems and tools. These SAPs will typically include selected altitude, ground speed, true track angle, roll angle, vertical rate and track angle rate.

'Squitter' Transmissions. A Mode S transponder will periodically emit an unsolicited transmission of position and other parameters. This transmission is commonly referred to as a 'Squitter'. The functionality can be used to support the passive acquisition of a Mode S target by either ground or airborne users. The 'Squitter' transmission is issued on the Mode S reply frequency 1090 MHz and its functionality includes the following:

a. **Acquisition Squitter**. Acquisition Squitter is used primarily by Airborne Collision Avoidance Systems (ACAS) and by ground-based 'multilateration' systems, particularly to support surface movement surveillance techniques. The Acquisition Squitter contains the unique ICAO 24-bit AA.

b. **Extended Squitter**. Mode S 1090 MHz 'Extended Squitter' is a means by which Mode S can provide Automatic Dependent Surveillance - Broadcast (ADS-B), which is a surveillance system based on unsolicited broadcasts of information from aircraft. The 'Extended Squitter' messages are transmitted every half second and contain additional information to the Acquisition Squitter, including position reports, altitude, aircraft

identity and other Aircraft Derived Data (ADD) parameters. It is one of the three recognised ADS-B data links and is sometimes referred to as 1090ES

6 Legal Aspect

This chapter will study the legal text regarding TCAS, pilots and controller responsibilities, and then looks at the practices and studies of other ANSPs and stakeholders.

6.1 Regulatory framework

There is a hierarchy in the rules and regulations with three levels as describe in the figure below:

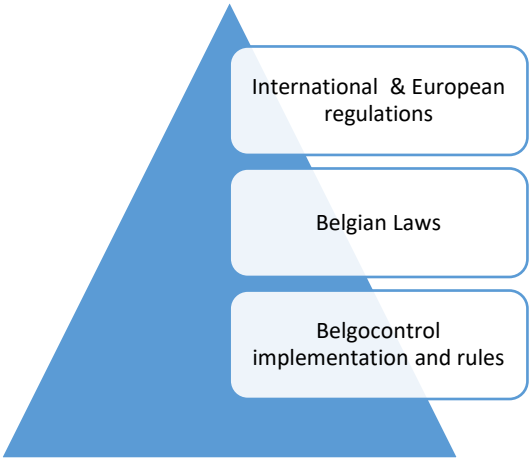


Figure 3 : Regulations hierarchy

However, the Belgium – GD Luxembourg AIP states that:
"The air traffic rules and procedures, applicable to air traffic in Belgium and the Grand Duchy of Luxembourg, conform to Commission Implementing Regulation (EU) No 923/2012 of 26 September 2012, to Annexes 2 and 11 to the Convention on International Civil Aviation and to those portions of the Procedures for Air Navigation Services, Rules of the Air and Air Traffic Services applicable to ACFT and of the Regional Supplementary Procedures applicable to the EUR Region. Where differences exist, the EU regulations supersede the ICAO standards."

When studying the legal text[17], it was found that there is a good uniformity in the rules which are in fact for the most part copy paste of each other.

The Rules of the Air, which can be found in the ICAO ANNEX 2[18], EU 923/2012[19] and Belgian law[20], states the followings

"*2.3.1 Responsibility of pilot-in-command*
The pilot-in-command of an aircraft shall, whether manipulating the controls or not, be responsible for the operation of the aircraft in accordance with the rules of the air, except that the pilot-in-command may depart from these rules in circumstances that render such departure absolutely necessary in the interests of safety.
3.2 Avoidance of collisions

[17] More complete relevant abstracts of the different texts can be found in 0
[18] {ANNEX2}
[19] {EU923}
[20] **Error! Reference source not found.**text exist only in French and Dutch, but are translated in this report.

Nothing in these rules shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision avoidance manoeuvres based on resolution advisories provided by ACAS equipment, as will best avert collision.
Note 1.— It is important that vigilance for the purpose of detecting potential collisions be exercised on board an aircraft, regardless of the type of flight or the class of airspace in which the aircraft is operating, and while operating on the movement area of an aerodrome."

The Belgian Rules of the Air includes also in the Art 3 & 37[21] the reporting obligations of the pilot to ATCO, ANSP services and BCAA.

The ICAO Doc 4444, EU 923/2012 and Belgocontrol V-Mats defines:

" *'air traffic control service' means a service provided for the purpose of:*
(a) preventing collisions:
(1) between aircraft; and
(2) on the manoeuvring area between aircraft and obstructions; and
(b) expediting and maintaining an orderly flow of air traffic;"

The PANS-ATM[22] contains the phraseology to be used by pilot and controller in case of TCAS RA. (see 0) and states the following ATM procedures regarding ACAS.

"***15.7.3 Procedures in regard to aircraft equipped with airborne collision avoidance systems (ACAS)***
15.7.3.1 The procedures to be applied for the provision of air traffic services to aircraft equipped with ACAS shall be identical to those applicable to non-ACAS equipped aircraft. In particular, the prevention of collisions, the establishment of appropriate separation and the information which might be provided in relation to conflicting traffic and to possible avoiding action shall conform with the normal ATS procedures and shall exclude consideration of aircraft capabilities dependent on ACAS equipment.
15.7.3.2 When a pilot reports an ACAS resolution advisory (RA), the controller shall not attempt to modify the aircraft flight path until the pilot reports "Clear of Conflict".
15.7.3.3 Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when:

a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance; or

b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and issues an alternative clearance which is acknowledged by the flight crew.

Note.— Pilots are required to report RAs which require a deviation from the current ATC clearance or instruction (see PANS-OPS (Doc 8168), Volume I, Part III, Section 3, Chapter 3, 3.2 c) 4)). This report informs the controller that a deviation from clearance or instruction is taking place in response to an ACAS RA.
15.7.3.4 Guidance on training of air traffic controllers in the application of ACAS events is contained in the Airborne Collision Avoidance System (ACAS) Manual (Doc 9863).

[21] See 00
[22] ICAO DOC 4444 {DOC4444}

15.7.3.5 ACAS can have a significant effect on ATC. Therefore, the performance of ACAS in the ATC environment should be monitored.
15.7.3.6 Following a significant ACAS event, pilots and controllers should complete an air traffic incident report.
Note 1.— The ACAS capability of an aircraft may not be known to air traffic controllers.
Note 2.— Operating procedures for use of ACAS are contained in PANS-OPS (Doc 8168), Volume I, Part III, Section 3, Chapter 3.
Note 3.— The phraseology to be used by controllers and pilots is contained in Chapter 12, 12.3.1.2."

The PANS-OPS[23] explains[24]:

- that the information provided by an ACAS is intended to assists pilots in the safe operation of aircraft by providing advice on appropriate action to reduce the risk of collision, using RAs, which proposes manoeuvres, and TA, which are intended to prompt visual acquisition and to act as a warning that an RA may follow.
- how the ACAS indications shall be used by pilots.
- that pilots should use appropriate procedures to avoid unnecessary ACAS II RAs in aircraft at or approaching adjacent altitudes or flight levels.
- the obligation and content of ACAS recurrent Training

The ACAS Manual[25] contains a lot of technical and procedural information. The 00contains the relevant abstracts describing:

- ANSP responsibilities regarding ACAS: maintenance of awareness of ACAS monitoring, training of ATC specialists on ACAS, provision of information to the CAA, MODE –C errors and follows-up.
- ACAS operational use by pilot
- ATCO's responsibility during an RA
- ACAS training programs for controllers
- Relationship between ACAS and STCA: they are independent and should be considered so. ACAS has more frequent surveillance update than STCA while STCA has more information than ACAS regarding intended flight path; the possible issuance of TCAS RA without STCA and vice-versa.

The interaction and responsibilities of pilot and controller are summarized in the table below.

ACAS Event Interaction	
Aircrew	**Controller**
Traffic Advisory TA	
Shall not manoeuvre their aircraft in response to traffic advisories (TAs) only Should prepare for appropriate action if an RA occurs; but as far as practicable. pilots should not request traffic information	Remains responsible for ATC separation If requested by the aircrew, shall give traffic information

[23] ICAO Doc 8168 {DOC8168}
[24] Relevant text abstracts can be found in 00
[25] ICAO DOC 9863 {DOC9863}

Resolution Advisory RA	
Shall respond immediately and manoeuvre as indicated, unless doing so would jeopardize the safety of the aeroplane Shall follow the RA even if there is a conflict between the RA and an ATC instruction to manoeuvre Shall never manoeuvre in the opposite sense to an RA, nor maintain a vertical rate in the opposite sense to an RA **When deviating from an ATC instruction or clearance in response to any RA**, shall: • as soon as permitted by flight crew workload, notify the appropriate ATC unit of the deviation; • immediately inform ATC when they are unable to comply with a clearance or instruction that conflicts with an RA Shall promptly comply with any subsequent RAs issued by ACAS Shall limit the alterations of the flight path to the minimum extent necessary to comply with the RAs	Shall not attempt to modify the flight path of an aircraft responding to an RA Shall not issue any clearance or instruction to the aircraft involved until the pilot reports returning to the terms of the assigned ATC clearance or instruction Shall acknowledge the report by using the phrase ROGER If requested by the aircrew, shall give traffic information Ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA
Clear of conflict	
Shall promptly return to the terms of the ATC instruction or clearance when the conflict is resolved Shall notify ATC after initiating a return to or resuming the current clearance	Shall resume responsibility for providing separation for all the affected aircraft when he acknowledges: • a report from the pilot that the aircraft is resuming the assigned ATC clearance or instruction and issues an alternative clearance or instruction which is acknowledged by the pilot • a report from the pilot that the aircraft has resumed the assigned ATC clearance or instruction

Table 1: ACAS event interaction

It's also important to notice that, additionally, the ACAS Manual states in chapter 6, 6.3.1.5.:

"The following points received emphasis during pilot training: […]
d) if possible, comply with the controller's clearance, e.g. turn to Intercept an airway or localizer, at the same time as responding to an RA; and […]"

ICAO provisions acknowledge the possibility of the display of the RA information to controllers but, current ICAO procedures do not contain provision for operational use of RA Downlink.

In 2011, the European Commission published Implementing Rule No 1332/2011 mandating, from 1 December 2015, the carriage of ACAS II (TCAS II) version 7.1 within European Union airspace by all civil aeroplanes with a MTOM exceeding 5700 kg or authorised to carry more than 19 passengers.

"Compliance with Commission Regulation (EU) No 1332/2011 is required by 01 December 2015 and no general exemptions provisions were included in the regulation that would permit continued operations or for the execution of a single flight, for whatever reason. Furthermore, the regulation does not distinguish the nature of the flight, therefore all flight with aircraft above 5700 kg or authorise to carry more than 19 passengers are within the scope of the regulation.

However, if operation within European Airspace with a non-compliant aircraft after the 01/12/2015 is necessary and an upgrade to ACAS II version 7.1 has been planned, it may be possible, based on Article 14.4 of the Basic Regulation for an exemption to be issued for a limited duration of time. Dependent upon the aircraft registration and the authority responsible for its operations will dictate from whom the exemption has to be requested.

- If the aircraft is registered in an EU member state or is registered in a third country and an EU member state is responsible for the operations, a 14.4 exemption from the national aviation authority responsible for the operation should be requested.
- If the aircraft is not on a European register or a non EU state is responsible the operational approval, exemptions need to be requested from each European State in whose airspace the aircraft is intended to be operated.

In both cases no Permit to Fly is necessary. Finally, operators should be aware that the likelihood of receiving such an exemption from each and every member state is very limited. However, in accordance with Article 3(2) of the regulation, states shall ensure that operation of state aircraft comply with the objective of regulation, therefore states may introduce specific measures to meet these objectives."[26]

Flying with an inoperative ACAS II is permitted provided it is done in accordance to the applicable Minimum Equipment List (MEL) provisions. Fault must be rectified within 10 days or less if so prescribed by the MEL.[27]

6.2 Best practices and stakeholders behaviors

6.2.1 Maastricht UAC[28]

The enhanced Mode S DAP are more used by Maastricht UAC.
The downlinked selected altitude is checked similar to the Belgocontrol Eurocat display but additionally other Enhanced Mode S parameters are available in a separate window:

- Mode S Aircraft Identification (ACID)
- Downlinked Selected Altitude (DSA, FSSA)
- Downlinked magnetic heading
- Downlinked Indicated Airspeed (IAS)
- Downlinked MACH number

[26] From http://easa.europa.eu/the-agency/faqs/airspace-usage-requirement-acas-ii-v71
[27] From {ACASII}. Remark: In Germany, it is limited to 3 days.
[28] **Error! Reference source not found.**

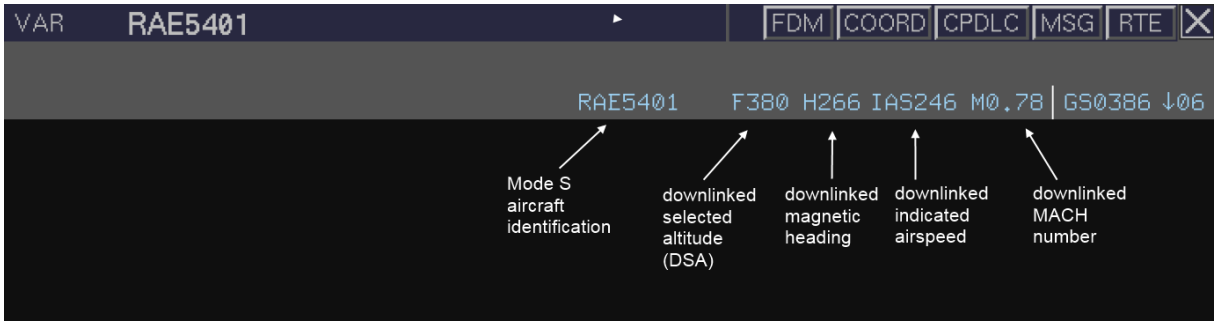


Figure 4 : EHS display MUAC

The DAP displayed to the controller could not only increase his/her awareness but avoid some communication to request such parameters.

BP_2	The display of DAP can increase the controller situation awareness but also reduce the number of communication.

6.2.2 Eurocontrol specialist interview

At the start of the second iteration, the surveyor and the mentor had the opportunity to meet Eurocontrol experts about TCAS RA Downlink, authors of several studies and reports (see {FARADS} {SSR_ACAS}& {Study}).

The experts confirmed the surveyor and mentor that there are no specific regulations about the TCAS RA Downlink display.

According to the experts the essential RA Downlink information (i.e. the type of RA) has never been found to contain any errors. However, some errors may appears in the intruder ID but that information is not used for the display. Sometime empty RA messages are transmitted to the ground due to faulty avionics. In the message count, empty messages amount for as much as 95% of messages; however, they can be easily identified (missing bits) and are filtered out before being presented for display.

The shortest the delay, the most effective the RA-Downlink display will be. The delay should be less than eight seconds for the information to be effective.

During this interview, Eurocontrol FARADS authors reported that the majority of their study's participants saw clear operational benefits in the provision of the RA information to the controller.

RA Downlink can:

- support the controller's anticipation of aircraft manoeuvres
- improve Controller general situational awareness regarding the aircraft involved in an RA and other aircraft in vicinity;
- increase the Controller's awareness of RA completion, thereby increasing the likelihood that the Controller would correctly resume responsibility for separation at that time;
- reduce the likelihood of contradictory clearances: if the controller is informed by downlink about the RA issued in the cockpit, it is highly unlikely that, given he/she issues a clearance, this clearance is contradictory to the RA.
- help prevent interruption to RAs due to a combination of Controllers inadvertently issuing clearances to RA incident aircraft and Pilots failing to comply with ICAO requirements to ignore ATC instructions when involved in an RA;

- lead to a reduction in RT, during RAs encounter, to the benefit of both Controller and Pilot during what can be a stressful event.[29]

With the pilot report of an RA, an en-route controller will be aware of an RA on average 29 seconds after the RA has occurred. With Mode-S RA Downlink, the controller will be aware of an RA in 95% of the cases within 8.9 seconds of their occurrence. So RA Downlink would be sufficiently timely to allow for a significant increase in the controller's awareness of the RA encounter.[30]

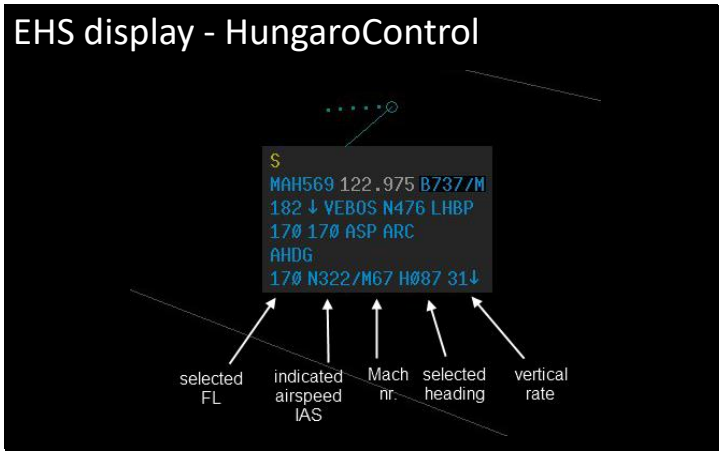
However, there are also potential disadvantages of RA Downlink. One is referred to as the "cognitive tunnelling hypothesis": according to this hypothesis, the display of RA information narrows the controller's attention to the RA event, on the expense of other traffic in the sector. That has been investigated during RADE simulations and no evidence of cognitive tunnelling was found. RAs that are due to high vertical rate before level-off are regarded by some controllers as nuisance alerts because, in the majority of cases, they do not result in a deviation from the cleared flight trajectory and, thus, are less relevant.[31]
One last argument against the RA Downlink is that it might mislead the ATCOs into believing that they are not responsible for separation.[32]

With regards to all those studies and discussion, the experts explains that

- Hungary and Czech republic were amongst the first adopter of the RA Downlink in Europe
- Luxembourg implemented it in 2009
- DFS is investigating and considering the implementation of it
- France and USA decided not to use it
- NATS cannot use it due to a UK CAA policy (see 6.2.4)
- MUAC has no plan for using it yet

6.2.3 HungaroControl Zrt.[33]

Currently the RA indication downlinked from the Mode S transponder is displayed in the radar label.



[29] Element found also in {FARADS} & {SSR_ACAS}
[30] {Study}
[31] {Study}
[32] {SSR_ACAS}
[33] E-mail exchange with SMU members of HungaroControl

Figure 5 : Enhanced Mode S data available in the track label from the HungaroControl Eurocat system[34]

The Hungarian national legislative documents only describe the responsibilities of the controller in the event of TCAS RA announced by the pilot. According to local regulations (approved by the CAA of Hungary), the TCAS RA Downlink shall be ignored from an operative point of view. In other words, it is only for situational awareness and informative purposes, and the controller shall not consider RA Downlink when issuing a new clearance. The national level regulation describes that the responsibility for separation still applies, unless the pilot verbally acknowledges the RA alert and announces that he/she intends to follow TCAS instructions. If and only if the controller suspects by the given circumstances that the RA Downlink is a false alert (by means of technical failure), a verbal confirmation from the pilot is requested.

In an event of TCAS RA Downlink indication the controller is allowed to issue a clearance, but the common practice is that we wait for pilot confirmation. HungaroControl safety unit have received only few comments regarding RA Downlink issues.

6.2.4 Air Navigation Services of Czech Republic

The Czech Republic ANSP display the RA Downlink "for information only" for years. The Czech system display a visual alert in the line 0 (above the call sign) in red indicating the sense of the RA as follows:

- RA↑ for Climb or increase climb
- RA↓ for Descent or increase descent
- RA for monitor vertical speed (preventive RA)
- RA – for Level OFF
- RA x for multiple RA (but never seen so far)

A their system guarantee a RA display delay of less than 2 seconds, the ATCOs are informed about possible deviation from ATC clearance based on RA much earlier than the pilot has a chance to report the RA by voice. The display is to be used as information only, the ATCO remains responsible for separation until the pilots reports the RA. Czech ATCOs are trained not to give contradictory instruction to the RA displayed to prevent some event like "Überlingen".

6.2.5 UK CAA[35]

CAA Policy is that ACAS RA Downlink data **shall not** be displayed to controllers on the surveillance display, for the following reasons:

- All RAs are downlinked without distinction between their type and nature, not just those that are required to be announced by the pilot on RT. In accordance with ICAO procedures contained within Doc 8168 (PANS-OPS), RAs which do not require a deviation from current ATC instructions or clearances (e.g. Monitor Vertical Speed, Maintain Vertical Speed, Maintain or Maintain Vertical Speed, Crossing Maintain) are not announced on RT.

[34] **Error! Reference source not found.**
[35] {CAA-SN}

- A downlinked RA without adequate discrimination may lead the ATCO to inappropriately cease the provision of ATC instructions. However, under current ICAO procedures, the controller will continue to provide ATC instructions during RA events that do not deviate from the clearance or instruction unless such a clearance is at variance with the RA, at which point the pilot will report 'UNABLE, TCAS RA'.
- There is no assurance as to the integrity of the RA downlink and absent or false downlink data could be a possibility.
- There are currently no ICAO, European or UK pilot procedures, ATC procedures or legal responsibilities for the use of ACAS RA Downlink. However, this subject is under consideration by Eurocontrol.

6.2.6 ICAO - Twelfth Air Navigation Conference[36]

Of the seven States and ANSP's that have implemented ACAS RA DL, three are currently disabled (Tokyo, Belfast, and Cardiff). Initial information indicates one of the reasons for disabling ACAS RA DL can be explained by the addition of another "alert" to a system of numerous alerts and an already clustered radar display. Furthermore, while independent consultants study and survey the issue of multiple alerts distraction, the RA display can create even more confusion for the ATCO when considering the likelihood of pilot compliance and if and when the ATCO is responsible again for separation. The result is a tremendous amount of ambiguity about what to do and what is expected from the ATCO when such a situation occurs.

Currently, there are three possible operational solutions of how ACAS-RA's down-linked to CWP's could be handled:

a) no ACAS RA DL displayed on CWP;
b) ACAS RA's displayed at CWP's "**for information only**", meaning no particular/special procedures are attached to this data, and no controller Eurocontrol is proposing an operational scenario where ATCO's shall stop transmitting flight-path modifying clearances to these aircraft once they are showing an ACAS-RA on their radar display. ATCO's would be required to consider ACAS RA's displayed as if receiving a voice report by the crew. *Note.– This will require an amendment to ICAO-SARPs.*

In some cases the delay at which ATCO's would become aware of an active ACAS RA present in their sector could be improved over current R/T procedures. This advance information has value only if the ATCO can be assured that the RA manoeuvre will be executed and that during the lapse of time – gained by the ACAS RA-D/L – an ATC clearance (contrary to the ACAS RA shown) would be transmitted to the aircraft involved in the RA manoeuvre.

Air traffic controllers are only aware that an RA has been issued once notified by the pilot via radio. Being unaware of an RA, the controller might instruct the aircraft to manoeuvre in a manner contrary to the RA. While the controller, unaware of the RA, is required to resolve an imminent conflict and assure safe separation, it must be stressed that the current ACAS procedures state that a crew confronted with an incompatible ATC-clearance during an active ACAS RA, should explicitly refuse the ATC-clearance, using the "UNABLE, TCAS RA" phraseology.

The conclusion of the conference is:

[36] {ICAO_WP}

1. Controllers are not aware of an ACAS event until notified by the crew, which has been problematic.
2. ACAS RA down linking to the controller work position may provide an additional level of awareness to preclude ATCO's from issuing conflicting instructions.
3. ACAS RA DL to CWP also creates unintended consequences such as operational problems associated with multiple alerts and radar display congestion, as well as safety issues relating to new procedures and uncertain responsibilities not incorporated in ICAO SARPs.

6.2.7 IFATCA Position[37]

Displaying TCAS Resolution Advisory (RA) information from aircraft on a controller's screen (or Controller Working Position - CWP) may seem to be useful information to assist controllers – however the information displayed may be wrong or outdated and therefore unsafe. IFATCA has clear policy regarding this. ICAO considers TCAS as a type of ACAS therefore IFATCA uses the term ACAS.

IFATCA opposes downlinking of any advisories generated by ACAS to controller working positions. Currently, the verbal report of a TCAS RA by a crew conveys the following three points to the ATCOs:

1. Yes, a TCAS RA is present,
2. Yes, we are following the RA,
3. Our manoeuvre makes us deviate from the current ATC-clearance.

The automatic downlink of a TCA RA to ATC does not confirm any of the three points.

If down linking of ACAS Resolution Advisories becomes mandated, then IFATCA can only accept this provided that the following criteria are met:

- Clear and unambiguous controller legal responsibilities;
- Downlink without delay;
- ATC system to be able to receive, process and display the down link to the appropriate control positions;
- Compatibility with all ground based safety nets;
- Nuisance and false alerts must be kept to an absolute minimum.

6.2.8 Airbus

Years before the Eurocontrol study, Airbus Group SE opted to equip its A380 and A350 jets with technology to automatically put the planes into the appropriate climb or descent trajectory, without any pilot action. The company incorporated the technology partly out of concern that pilots would react too slowly or otherwise incorrectly to warnings. Crews are trained to respond within a few seconds. {Press}

A TCAS Alert Prevention (TCAP) functionality has been introduced by Airbus to prevent the generation of RA in 1000-foot level-off geometries. The functionality uses a new altitude capture law for flight guidance computers, which decreases aircraft's vertical rate towards the selected altitude, once a TA has been generated and the auto-pilot and/or flight director are

[37] {IFAT} + {HS22} « Why TCAS Downlinking is a bad idea » abstracts

engaged, when another aircraft is known to be in the vicinity. The TCAP functionality is complementary to the flight guidance computer's conventional altitude capture function.[38]

6.3 Legal Analysis

6.3.1 TCAS RA display to Controllers: legal assessment by Eurocontrol and DFS legal services[39]

Eurocontrol and DFS legal services made a legal assessment on the "responsibilities for providing separation" when the TCAS RA is displayed. The important arguments and conclusions are as follows.

It should be said that the word 'responsibility' intrinsically has a legal connotation. Responsibility is the obligation to personally fulfil a duty, requiring accountability for actions taken or decisions made. Such duty is created not only by relevant legal regulations governing the provisions of the service, but also by the relationship which exists between the controller and the pilot.

It is worth noting that a duty can consist not only in performing certain acts, but also in abstaining or refraining from carrying out such (negative obligation). One example is ICAO DOC4444 provision 15.7.3.2[40], specifically imposing a duty on the controller not to issue clearances for the aircraft that has reported a TCAS RA, in order to avoid the issuance of conflicting instructions. The controller bears legal responsibility for adhering to this prohibition in the same way he is responsible for the performance of positive obligations, i.e. the duty to issue separation clearances in normal circumstances. It is submitted that it should be examined from an operational and legal perspective to formulate provision 15.7.3.3[41] as negative obligation similar to 15.7.3.2, in order to improve its clarity.

UK CAA maintains that the depth and boundaries of pilot/controller duty cannot be defined in advance and will only ultimately be decided by the court when examining the specifics of the situation at hand.

There is an increase tendency of courts holding ATCOs liable for the negligent performance of their duties, irrespectively of whether such duty is incorporated in the controller's manual or not, which is why it is important to have internationally applicable rules that clearly state when the controller is relieved of the duty to provide separation, and hence also the legal responsibility for its correct performance.

Since, as discussed above, TCAS RAs have an impact on the responsibility of controllers for the provision of separation, it is necessary to determine the extent of such responsibility. While PANS-ATM is unambiguous as to when the controller ceases to be responsible for the

---

[38] {Airbus}

[39] {FLIMSY}

[40] "15.7.3.2 When a pilot reports an ACAS resolution advisory (RA), the controller shall not attempt to modify theaircraft flight path until the pilot reports "Clear of Conflict"."

[41] "15.7.3.3 Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when:
a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance; or
b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and issues an alternative clearance which is acknowledged by the flight crew."

separation and later resumes responsibility, it does not clearly define the scope of aircraft no longer requiring ATC separation.

Provision 15.7.3.3 of PANS-ATM makes reference to the aircraft that departs from its ATC clearance or reports an RA, but also to "aircraft affected as a direct consequence of the manoeuvre induced by the RA". From an operational point of view, it seems to be very difficult to precisely predefine this constellation, as the number of aircraft involved will depend on the specific situation and the instructions given by the TCAS equipment.

Upon being informed of an issued RA, the controller will definitely cease to be responsible for separating that aircraft from other traffic. However, while climbing or descending in accordance with the RA, this aircraft might end up on conflicting paths with other aircraft flying on a higher or lower flight level. As long as this triggers new RAs, controllers should be relieved of responsibility for providing separation for such traffic, since this is in line with the original purpose of rule 15.7.3.3.

However, the ambiguity of rule 15.7.3.3, as currently worded, lies in the fact that it can also be interpreted as encompassing aircraft that have not yet issued RAs even if they have become affected by the RA-induced deviation of the original aircraft. To relieve controllers from responsibility in this case may be undesirable, as it would entail, for a number of aircraft, the loss of ATC service, which, however brief, may seriously compromise safety and greatly reduce the situational awareness of controllers.

For this reason, the suggested merger of provisions 15.7.3.2 and 15.7.3.3 in a single, concise rule seems appropriate, as by limiting the notion of "affected aircraft" to those that have issued RAs, it would resolve the ambiguity and clarify the extent of the controller's responsibility for providing separation, as well as formulating more clearly the negative obligation not to modify the flight path until the situation is resolved. With a view to a possible implementation of RA Downlink, from a legal perspective it may perhaps also be worth considering the following wording:

15.7.3.2 Once informed of an RA, the controller:

a) ceases to be responsible for providing separation for that aircraft; and

b) shall not attempt to modify the aircraft flight path until informed of "Clear of Conflict".

as an alternative to the proposal focusing on pilot reporting. This broader phrase would cover RA Downlinks as well as pilot reporting, and might be less susceptible to amendment in the long term, should relevant systems be implemented in the future.

6.3.2 Belgocontrol legal Cell

The BGATC submitted worries about the legal liability in case of accident/incident in the present situation.

The following questions remains, if we have an accident/incident what are the risks:

1. If the controller uses the information displayed?
2. If Belgocontrol does not display an available information to the controller?

The answers cannot be defined in advance and will only ultimately be decided by the court when examining the specifics of the situation at hand.

Nevertheless, the display of the RA downlink information on the controller HMI is not a problem as long as it is used as information only to increase the situation awareness and this is clearly depicted in controller's procedures.

International, EU and Belgian regulations are clear. ATCO's job is to prevent collision between aircraft and provide separation according to the airspace classification. The display of the RA information on the HMI does not confirm the RA and does not remove any responsibility from the controller. The regulations states that only "Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA"[42]

As long as an aircraft does not depart from its ATC clearance/instruction in compliance with an RA, or there is no report of a TCAS RA from the pilot, it is the controller obligation to continue his/her job and to prevent a collision by issuing instructions even without answer of the pilot. It is the responsibility of the pilot to declare the RA and to inform the ATCO that he/she will disregard the ATC instruction to follow the RA by using the appropriate phraseology (see 0)

Role and responsibilities are clearly stated in the regulations and the display of the RA information has no impact on them.

6.3.3 Conclusion

Regarding the behaviour, arguments described here above, it can be concluded that there is a consensus to disagree about the use of the RA Downlink; even if there is a good uniformity in regulations at all levels.

The ACAS system was made as an ultimate anti-collision system. According to the Author, it is not a good idea that ATCO's become an additional party in the procedure, as suggested by the DFS-Eurocontrol Study, as it may reduce its efficiency. Moreover, not every ANSP as a RA-Downlink tool, so how would a pilot know when ATC is not providing service due to a RA display. The DFS-Eurocontrol suggestion can create more confusion for pilot with regard of the service they are receiving when not deviating from the ATC clearance but responding to a preventive RA (which should not be reported). The procedure described in the regulations should remain the same.

As the automatic downlink of a TCAS RA to ATC does not confirm that the pilot is replying to the RA or will deviate from the ATC clearance; it should not be use as sole source of information.

If the RA display may help the ATCO to improve his/her situation awareness and prevent the issuance of contradictory clearances, it does not change anything in the roles and responsibilities of the ATCOs and pilots with regards to the regulations already mentioned. Nevertheless, this should be translated in the Belgocontrol ATC manual and procedures as it was described in the CANAC[2] project documentation and linked Notes to Controllers.

[42] {DOC4444} 15.7.3.3

7 TCAS reports analysis (Belgocontrol / BCAA)

Through various monitoring programmes and data obtained from operators, it is estimated that an RA occurs approximately every 1000 flight hours on short and medium haul. The number increases to 3000 hours for long haul aircraft. The most common observed RA was the Adjust Vertical Speed which amounted for 67% of all RAs, followed by Climb (13%) and Descend (9%). Experience shows that in the majority of cases (80%) only one aircraft will receive an RA (regardless of whether the intruder is TCAS II aircraft or not).[43]

An SMU staff member reported that, according to a MUAC study, 75% of the RAs are unnecessary RAs. This means that the controllers' instructions were clear and if respected no risk of collision existed. Most of the unnecessary TCAS RA are due to HVR climb and descent of the aircrafts to adjacent FL[44] so triggering the RA. This problem was already pointed in the regulations PANS-OPS & ACAS – Manual (see 12)

In view to have a better picture of the situation in Belgium and for Belgocontrol, TCAS reports figures from the BCAA and Belgocontrol were analysed.

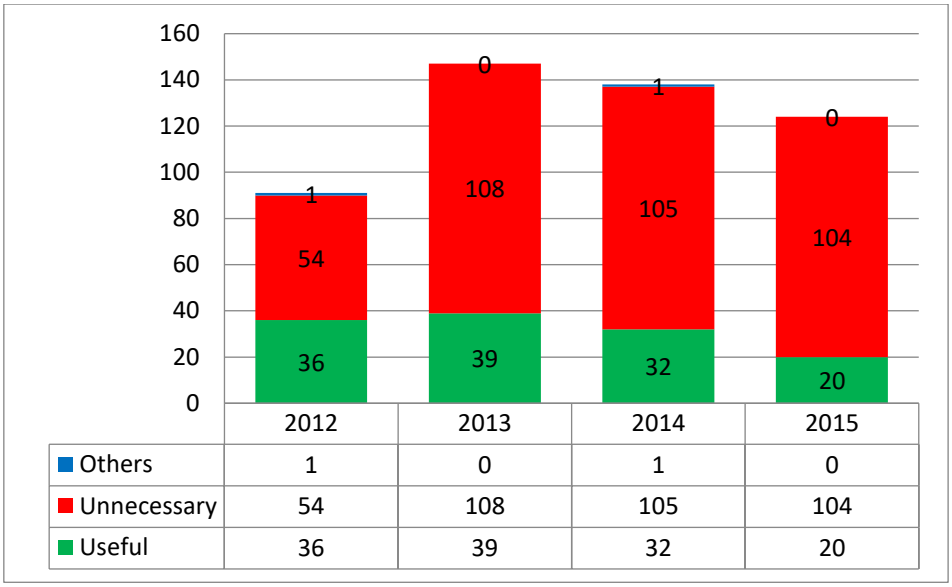
7.1 DGTA figures

These figures include all the TCAS reports for the Belgian airspace. This means reports from Belgocontrol ATCOs, MUAC ATCOs and pilots overflying Belgium.

The reports were classified as:

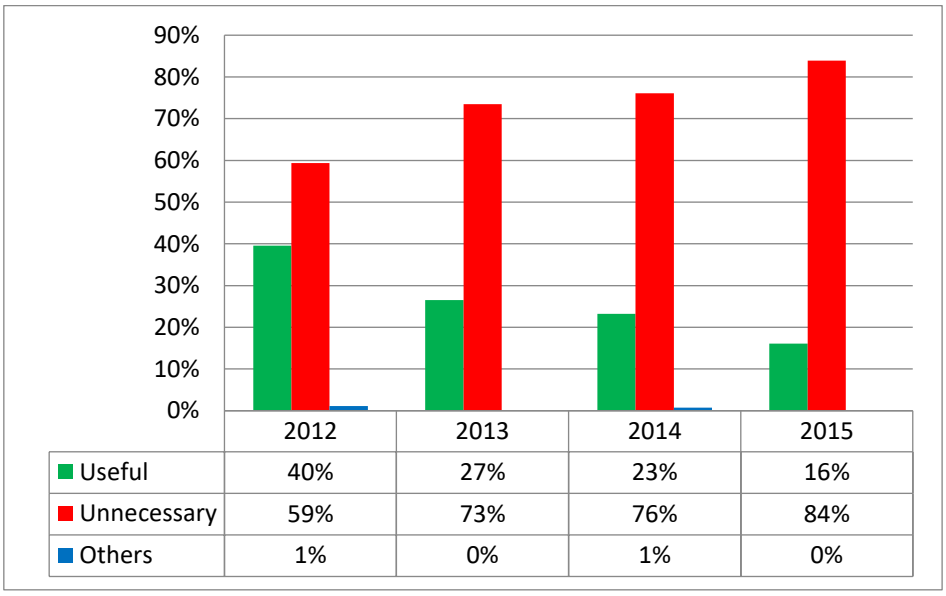
- useful, meaning the TCAS plays his role in the avoidance of a potential collision, or
- unnecessary , meaning that a TCAS RA was triggered but the clearance, instructions and actions of the controller where correct and if respected would not have lead to a lost of separation or a collision, or
- others, meaning that not enough data about the event are available or situation/analisys does not permit to classified the report in one of the 2 previous category

[43] {ACASII}
[44] Adjacent FL means FL separated by 1000ft; eg: FL200 & FL210



	2012	2013	2014	2015
Others	1	0	1	0
Unnecessary	54	108	105	104
Useful	36	39	32	20

Figure 6: DGTA TCAS Report analysis - absolute value



	2012	2013	2014	2015
Useful	40%	27%	23%	16%
Unnecessary	59%	73%	76%	84%
Others	1%	0%	1%	0%

Figure 7: DGTA TCAS report analysis – percentage

We can notice from the previous graphics that the number of TCAS report are quite low regarding the annual traffic amount overhead Belgium. The number of TCAS report is also decreasing since 2013.

One interesting information is also that the number of useful TCAS is reducing, meaning that controller are performing well. Nevertheless, we can also see that the proportion of unnecessary TCAS RA is increasing, even if relatively stable in absolute value.

According to the information gathered during the survey, most of those unnecessary TCAS are due to HVR event as already mentioned above.

8 Conclusions and Recommendations

Most of the time, ATCOs only become aware of an RA if they are informed by the pilot. This often happen late or not at all, often due to good reasons such as high workload in the cockpit following the RA. This leads to the risk that the controller may unknowingly provide a contradictory instruction. As The ACAS system was made as an ultimate anti-collision system, the RA Downlink is intended to reduce the risk of inadvertent ATC intervention in an RA, as well as help to prevent consequential conflicts, through improvements in controller situational awareness.

If the RA display may help the ATCO to improve his/her situation awareness and the issuance of contradictory clearances, it does not change anything in the roles and responsibilities of the ATCOs and pilots. International, EU and Belgian regulations are clear. ATCO's job is to prevent collision between aircraft and provide separation according to the airspace classification. The display of the RA information on the HMI does not confirm that the pilot is replying to the RA or will deviate from the ATC clearance; it should not be used as sole source of information and does not remove any responsibility from the controller. The regulations states that only "Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA"[45]. As long as an aircraft does not depart from its ATC clearance/instruction in compliance with an RA, or there is no report of a TCAS RA from the pilot, it is the controller obligation to continue his/her job and to prevent a collision by issuing instructions even without answer of the pilot. It is the responsibility of the pilot to declare the RA and to inform the ATCO that he/she will disregard the ATC instruction to follow the RA by using the appropriate phraseology (see 0). Role and responsibilities are clearly stated in the regulations and the display of the RA information has no impact on them.

With or without the RA Downlink display on the HMI, in case of accident/incident, risks and judicial final responsibilities will only ultimately be decided by the court when examining the specifics of the situation at hand.

Different studies, the questionnaires used during this survey and the interviews performed show that the RA Downlink can have a positive impact on the controller awareness and reaction. It triggers good reactions: more traffic information and review of the planning to take into account the recovery of the RA event.

In conclusion, it is recommended to keep the RA Downlink displayed on the HMI as an information tool only, as such the linked audio alert shall be switched off. The RA Downlink display and use shall be clearly depicted in controllers' procedures and manuals, and regular training performed.

[45] {DOC4444} 15.7.3.3

9 References

{ACASII} Textual Title: Overview of ACAS II (incorporating version 7.1)
Version: 3.0
Reference: www.eurocontrol.int/acas
Date: 2012-01-12
Organization Eurocontrol

{ACAS_X} Textual Title: ACAS X
Doc ID: NETALERT – the Safety Nets newsletter N°17
Reference: http://www.skybrary.aero/bookshelf/books/2390.pdf
Date: June 2013
Organization Eurocontrol

{Airbus} Textual Title: TCAS Alert Prevention (TCAP)
Reference: http://www.technology-licensing.com/etl/int/en/What-we-offer/Technologies-for-licensing/Safety-related-and-homeland-security-technologies/TCAS-Alert-Prevention-TCAP.html
Date: N/A
Organization AIRBUS Group

{ANNEX2} Textual Title: Rules of the Air
Doc ID: Annex 2 to the Convention on International Civil Aviation
Version: Tenth Edition
Date: July 2005
Organization: ICAO

{ANNEX10} Textual Title: International Standards and Recommended Practices – Surveillance and Collision Avoidance Systems
Doc ID: Annex 10 vol 4 to the Convention on International Civil Aviation
Version: Fourth Edition
Date: July 2007
Organization: ICAO

{CAA-SN} Textual Title: Notification of CAA Policy Regarding Downlink and Display of Airborne Collision Avoidance System Resolution Advisory Data
Doc ID: SN-2013/017
Date: 2013
Organization: UK CAA

{CAA-PA} Textual Title: Proposal to amend the air navigation order 2005 for the purpose of improving the technical interoperability of all aircraft in UK airspace.
Version: 1.2
Date: N/A
Organization: UK CAA

{DOC4444} Textual Title: Air Traffic Management
Doc ID: Doc 4444 ATM/501
Version: 15th edition

Date: 2007-11-22
Organization: ICAO

{DOC8168} Textual Title: Aircraft Operations – Vol I Flight Procedures
Doc ID: Doc 8168 AN/611
Version: 5th Edition
Date: 2010
Organization: ICAO

{DOC9863} Textual Title: Airborne Collision Avoidance System (ACAS) Manual
Doc ID: Doc 9863 AN/461
Version: Second Edition
Date: 2012
Organization: ICAO

{ESASSP1} Textual Title: Eurocontrol Specification for ATM Surveillance System Performance (Volume1)
Version: 1.1
Reference: EUROCONTROL-SPEC-147
ISBN: 978-2-87497-022-1
Date: September 2015
Organization Eurocontrol

{ESASSP2} Textual Title: Eurocontrol Specification for ATM Surveillance System Performance (Volume2 Appendices)
Version: 1.0
Reference: EUROCONTROL-SPEC-0147
ISBN: 978-2-87497-022-1
Date: March 2012
Organization Eurocontrol

{EU923} Textual Title: Regulations laying down the common rules of the air and operational
provisions regarding services and procedures in air navigation […]
Doc ID: EU 923/2012
Version: N/A
Date: 2012-09-26
Organization: EU Commission

{EU1332} Textual Title: Regulations laying down common airspace usage requirements and
operating procedures for airborne collision avoidance
Doc ID: EU 923/2012
Version: N/A
Date: 2012-10-13
Organization: EU Commission

{FARADS} Textual Title: FARADS (Feasibility of ACAS RA Downlink Study)
Version: 1.0
Date: 2007-05-14
Organization: Eurocontrol

{FLIMSY} Textual Title: TCAS RA Display to Controllers: legal assessment
Version: N/A
Date: N/A
Organization: Eurocontrol & DFS legal services

{HS22} Textual Title: Safety Nets
Doc ID: HindSight 22
Date: Winter 2015
Organization: Eurocontrol

{ICAO_WP} Textual Title: Twelfth Air Navigation Conference-Montréal 19 to 30 November 2012
Doc ID: ANF-Conf/12-WP/151
Date: 2012-10-30
Organization ICAO

{IFAT} Textual Title: Displaying TCAS RAs on Controller Working Positions
Reference: http://www.ifatca.org/dossier_tcas_dl
Date: N/A
Organization IFATCA

{NetAlert} Textual Title: STCA and TCAS compatible safety nets
Doc ID: NETALERT Newsletter N°13
Reference: http://www.skybrary.aero/bookshelf/books/1807.pdf
Date: December 2011
Organization Eurocontrol

{Press} Textual Title: Risks from In-Flight Pilot Error Persist • Eurocontrol study finds
quarter of pilots fail to take correct action when alarms go off
Reference: www.kathrynsreport.com/2015/12/risks-from-in-flight-pilot-error.html?m=1
Date: 2015-12-10
Organization Internet –Wall Street Journal By Andy Pasztor

{SES_IVT} Textual Title: IVT Expert Report performed for Exercise VP-066
Version: 1.0
Date: 2015-05-08
Organization: SESAR

{SKYB_1} Textual Title: ATC Avoiding Instructions Opposite to TCAS RA
Reference: www.skybrary.aero/index.php/ATC_Avoiding_Instructions_Opposite_to_TCAS_RA
Date: 2014-05-06
Organization Eurocontrol Skybrary

{SKYB_2} Textual Title: Safety Nets
Reference: http://www.skybrary.aero/index.php/Safety_Nets
Date: 2015-12-24
Organization Eurocontrol Skybrary

{SKYB_RA} Textual Title: RA Downlink
Reference: http://www.skybrary.aero/index.php/RA_Downlink

Date: 2015-08-22
Organization Eurocontrol Skybrary

{Study} Textual Title: Operational Impact of RA Downlink: Results of Real-Time Simulation
Author: Stanislaw Drozdowski, Doris M. Dehn, Jürgen Teutsch & Bernd Lorenz
Version: N/A
Date: N/A
Organization: Eurocontrol & NLR

{SSR_ACAS}Textual Title: ACAS RA Downlink Safety Summary report
Version: 1.3
Date: 2007-05-31
Organization: Eurocontrol

10 Appendix A. Regulatory documents abstracts

A-1 ICAO documents

A-1.1 Annex 2 - Rules of the air

2.3.1 Responsibility of pilot-in-command
The pilot-in-command of an aircraft shall, whether manipulating the controls or not, be responsible for the operation of the aircraft in accordance with the rules of the air, except that the pilot-in-command may depart from these rules in circumstances that render such departure absolutely necessary in the interests of safety.

3.2 Avoidance of collisions
Nothing in these rules shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision avoidance manoeuvres based on resolution advisories provided by ACAS equipment, as will best avert collision.
Note 1.— It is important that vigilance for the purpose of detecting potential collisions be exercised on board an aircraft, regardless of the type of flight or the class of airspace in which the aircraft is operating, and while operating on the movement area of an aerodrome.
Note 2.— Operating procedures for use of ACAS detailing the responsibilities of the pilot-in-command are contained in PANS-OPS (Doc 8168), Volume I, Part VIII, Chapter 3.
Note 3.— Carriage requirements for ACAS equipment are addressed in Annex 6, Part I, Chapter 6 and Part II, Chapter 6.

A-1.2 PANS ATM - DOC 4444 – Air Traffic Management

15.7.3 Procedures in regard to aircraft equipped with airborne collision avoidance systems (ACAS)
15.7.3.1 The procedures to be applied for the provision of air traffic services to aircraft equipped with ACAS shall be identical to those applicable to non-ACAS equipped aircraft. In particular, the prevention of collisions, the establishment of appropriate separation and the information which might be provided in relation to conflicting traffic and to possible avoiding action shall conform with the normal ATS procedures and shall exclude consideration of aircraft capabilities dependent on ACAS equipment.
15.7.3.2 When a pilot reports an ACAS resolution advisory (RA), the controller shall not attempt to modify the aircraft flight path until the pilot reports “Clear of Conflict”.
15.7.3.3 Once an aircraft departs from its ATC clearance or instruction in compliance with an RA, or a pilot reports an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when:

a) the controller acknowledges a report from the flight crew that the aircraft has resumed the current clearance; or
b) the controller acknowledges a report from the flight crew that the aircraft is resuming the current clearance and
issues an alternative clearance which is acknowledged by the flight crew.

Note.— Pilots are required to report RAs which require a deviation from the current ATC clearance or instruction (see PANS-OPS (Doc 8168), Volume I, Part III, Section 3, Chapter 3,

3.2 c) 4)). This report informs the controller that a deviation from clearance or instruction is taking place in response to an ACAS RA.
15.7.3.4 Guidance on training of air traffic controllers in the application of ACAS events is contained in the *Airborne Collision Avoidance System (ACAS) Manual* (Doc 9863).
15.7.3.5 ACAS can have a significant effect on ATC. Therefore, the performance of ACAS in the ATC environment should be monitored.
15.7.3.6 Following a significant ACAS event, pilots and controllers should complete an air traffic incident report.
Note 1.— The ACAS capability of an aircraft may not be known to air traffic controllers.
Note 2.— Operating procedures for use of ACAS are contained in PANS-OPS (Doc 8168), Volume I, Part III, Section 3, Chapter 3.
Note 3.— The phraseology to be used by controllers and pilots is contained in Chapter 12, 12.3.1.2.

A-1.3 PANS-OPS - DOC 8168 – Air Navigation Services

Chapter 3
OPERATION OF AIRBORNE COLLISION AVOIDANCE SYSTEM (ACAS) EQUIPMENT
3.1 ACAS OVERVIEW
3.1.1 The information provided by an ACAS is intended to assist pilots in the safe operation of aircraft by providing advice on appropriate action to reduce the risk of collision. This is achieved through resolution advisories (RAs), which propose manoeuvres, and through traffic advisories (TAs), which are intended to prompt visual acquisition and to act as a warning that an RA may follow. TAs indicate the approximate positions of intruding aircraft that may later cause resolution advisories. RAs propose vertical manoeuvres that are predicted to increase or maintain separation from threatening aircraft. ACAS I equipment is only capable of providing TAs, while ACAS II is capable of providing both TAs and RAs. In this chapter, reference to ACAS means ACAS II.
3.1.2 ACAS indications shall be used by pilots in the avoidance of potential collisions, the enhancement of situational awareness, and the active search for, and visual acquisition of, conflicting traffic.
3.1.3 Nothing in the procedures specified in 3.2 hereunder shall prevent pilots-in-command from exercising their best judgement and full authority in the choice of the best course of action to resolve a traffic conflict or avert a potentia1 collision.
Note 1.— The ability of ACAS to fulfil its role of assisting pilots in the avoidance of potential collisions is dependent on the correct and timely response by pilots to ACAS indications. Operational experience has shown that the correct response by pilots is dependent on the effectiveness of the initial and recurrent training in ACAS procedures.
Note 2.— The normal operating mode of ACAS is TA/RA. The TA-only mode of operation is used in certain aircraft performance limiting conditions caused by in-flight failures or as otherwise promulgated by the appropriate authority.
Note 3.— ACAS Training Guidelines for Pilots are provided in the Attachment, "ACAS Training Guidelines for Pilots".

3.2 USE OF ACAS INDICATORS
The indications generated by ACAS shall be used by pilots in conformity with the following safety considerations:
a) pilots shall not manoeuvre their aircraft in response to traffic advisories (TAs) only;

Note 1.— TAs are intended to alert pilots to the possibility of a resolution advisory (RA), to enhance situational awareness, and to assist in visual acquisition of conflicting traffic. However, visually acquired traffic may not be the same traffic causing a TA. Visual perception of an encounter may be misleading, particularly at night.
Note 2.— The above restriction in the use of TAs is due to the limited bearing accuracy and to the difficulty in interpreting altitude rate from displayed traffic information.
b) on receipt of a TA, pilots shall use all available information to prepare for appropriate action if an RA occurs; and
c) in the event of an RA, pilots shall:

1) respond immediately by following the RA as indicated, unless doing so would jeopardize the safety of the aeroplane;
Note 1.— Stall warning, wind shear, and ground proximity warning system alerts have precedence over ACAS.
Note 2.— Visually acquired traffic may not be the same traffic causing an RA. Visual perception of an encounter may be misleading, particularly at night.
2) follow the RA even if there is a conflict between the RA and an air traffic control (ATC) instruction to manoeuvre;
3) not manoeuvre in the opposite sense to an RA;
Note.— In the case of an ACAS-ACAS coordinated encounter, the RAs complement each other in order to reduce the potential for collision. Manoeuvres, or lack of manoeuvres, that result in vertical rates opposite to the sense of an RA could result in a collision with the intruder aircraft.
4) as soon as possible, as permitted by flight crew workload, notify the appropriate ATC unit of any RA which requires a deviation from the current ATC instruction or clearance;
Note.— Unless informed by the pilot, ATC does not know when ACAS issues RAs. It is possible for ATC to issue instructions that are unknowingly contrary to ACAS RA indications. Therefore, it is important that ATC be notified when an ATC instruction or clearance is not being followed because it conflicts with an RA.
5) promptly comply with any modified RAs;
6) limit the alterations of the flight path to the minimum extent necessary to comply with the RAs;
7) promptly return to the terms of the ATC instruction or clearance when the conflict is resolved; and
8) notify ATC when returning to the current clearance.
Note.— Procedures in regard to ACAS-equipped aircraft and the phraseology to be used for the notification of manoeuvres in response to a resolution advisory are contained in the PANS-ATM (Doc 4444), Chapters 15 and 12 respectively.

3.3 HIGH VERTICAL RATE (HVR) ENCOUNTERS

Pilots should use appropriate procedures by which an aeroplane climbing or descending to an assigned altitude or flight level, especially with an autopilot engaged, may do so at a rate less than 8 m/s (or 1 500 ft/min) throughout the last 300 m (or 1 000 ft) of climb or descent to the assigned altitude or flight level when the pilot is made aware of another aircraft at or approaching an adjacent altitude or flight level, unless otherwise instructed by ATC. These procedures are intended to avoid unnecessary ACAS II resolution advisories in aircraft at or approaching adjacent altitudes or flight levels. For commercial operations, these procedures should be specified by the operator. Detailed information on HVR encounters and guidance material concerning the development of appropriate procedures is contained in Attachment B to this part.

[…]

5. ACAS RECURRENT TRAINING

5.1 ACAS recurrent training ensures that pilots maintain the appropriate ACAS knowledge and skills. ACAS recurrent training should be integrated into and/or conducted in conjunction with other established recurrent training programmes. An essential item of recurrent training is the discussion of any significant issues and operational concerns that have been identified by the operator.

A-1.4 ACAS Manual – DOC 9863

2.2.2 Air navigation services provider (ANSP) responsibilities

The ANSP, which has the delegated responsibility of providing air traffic services, should:

a) maintain awareness of ACAS operational monitoring activities conducted by States and international organizations;

b) train ATC specialists on ACAS and expected flight crew responses to ACAS advisories and provide familiarization flights for specialists on ACAS-equipped aircraft whenever possible;

c) provide pertinent CAA offices with data and information about ACAS ATC compatibility issues, e.g. airspace or airports where excessive numbers of RAs occur, hazardous conditions, situations or events which may be related to ACAS. Information on such issues should also be coordinated with other ANSPs and organizations; and

d) ensure that procedures are in place that implement the requirements of PANS-ATM especially those related to the discontinuance of Mode C reports when erroneous Mode C reports in excess of 60 m (200 ft) are detected. In addition, the ANSP should implement a means of following up with the operators of aircraft observed with erroneous altitude reporting to ensure they take the necessary actions to correct the anomalous performance of the transponder.

[…]

5.2.1.14 If an RA manoeuvre is inconsistent with the current ATC clearance, pilots shall follow the RA.

5.2.3.1 To preclude unnecessary transponder interrogations and possible interference with ground radar surveillance systems, ACAS should not be activated (TA-only or TA/RA mode) until taking the active runway for departure and should be deactivated immediately after clearing the runway after landing. To facilitate surveillance of surface movements, it is necessary to select a mode in which the Mode S transponder can nevertheless squitter and respond to discrete interrogations while taxiing to and from the gate. Operators must ensure that procedures exist for pilots and crews to be able to select the operating mode where ACAS is disabled, but the Mode S transponder remains active.

5.2.3.2 During flight, ACAS traffic displays should be used to assist in visual acquisition. Displays that have a range selection capability should be used in an appropriate range setting for the phase of flight. For example, use minimum range settings in the terminal area and longer ranges for climb/descent and cruise, as appropriate.

5.2.3.3 The normal operating mode of ACAS is TA/RA. It may be appropriate to operate ACAS in the TA-only mode only in conditions where States have approved specific procedures permitting aircraft to operate in close proximity or in the event of particular in-flight failures or performance limiting conditions as specified by the Aeroplane Flight Manual or operator. It should be noted that operating in TA-only mode eliminates the major safety benefit of ACAS.

5.2.3.3.1 Operating in TA/RA mode and then not following an RA is potentially dangerous. If an aircraft does not intend to respond to an RA and operates in the TA-only mode, other ACAS-equipped aircraft operating in TA/RA mode will have maximum flexibility in issuing RAs to resolve encounters.

5.2.3.4 When safe, practical, and in accordance with an operator's approved operating procedures, pilots should limit vertical speeds to 7.6 m/s (1 500 fpm) or less (depending on performance characteristics of the aircraft) when within 305 m (1 000 ft) of assigned altitudes. This procedure will reduce the frequency of unnecessary RAs and be in conformity with the ICAO guidance contained in PANS-OPS.
[…]

6.2 **ACAS TRAINING PROGRAMMES**
6.2.1 ACAS training should be included in all phases of air traffic controller training, starting as a part of the initial training for student air traffic controllers and ending in specific safety briefings after major incidents. Continuous training should be provided either by using regular ATC simulator runs or with special CBT tools like RITA (Replay Interface for TCAS Alerts), a dynamic graphical tool showing TCAS events from both the pilots' and controllers' perspectives.
6.2.4 Following the theoretical instruction, initial practical exercises should be conducted (e.g. ATC simulator runs or replays of specific ACAS events). The benefit of performing specific ACAS simulator training is that controllers will not be surprised when they have a real ACAS event in their operational environment.
6.2.5 In addition to the initial training described above, ACAS events should be incorporated in the practical simulator training of controllers. The choice of events should be designed to show controllers the different types of ACAS events and the variations in the responses of pilots. Additionally the controllers should practice the correct procedures and appropriate communication with the pilot. Once the ACAS event has finished, the controller should demonstrate the transition of the affected aircraft to the original clearance or instruction, or the integration into the new traffic scenario.
6.2.6 It is important for controllers to maintain their knowledge about ACAS. Therefore, ACAS should be integrated as a part of the safety or unusual incident content in the regular refresher or CBT-training courses for all active controllers. This will ensure that the controllers stay familiar with the ACAS procedures and regulatory requirements.
6.2.7 Whenever a major incident or safety issue occurs, ANSPs should develop a safety briefing or presentation, which includes all operational and technical aspects related to this particular event. The briefing should be held as soon as possible after the event to clarify this specific situation and should have mandatory participation.
6.2.8 Due to the incorporation of ACAS into the airspace and operational procedure development, specific ACAS training may be necessary before a new airspace design or ATC procedure can be introduced. The scope of this training will depend on the complexity and size of the planned implementation and can have a major influence on the entire development, even if there was initially no obvious connection to ACAS.
6.2.9 The ANSP is responsible for training controllers and other ATC specialists on ACAS and on expected flight crew responses to ACAS advisories. Familiarization flights for such specialists on ACAs-equipped aircraft should be made available.
[…]

6.3.1.5 When an RA is issued, pilots are expected to respond immediately to the RA unless doing so would jeopardize the safe operation of the flight. This means that aircraft will at times manoeuvre contrary to ATC instructions or disregard ATC instructions. The following points receive emphasis during pilot training:

a) do not manoeuvre in a direction opposite to that indicated by the RA because this may result in a collision;

b) inform the controller of the RA as soon as permitted by flight crew workload after responding to the RA. There is no requirement to make this notification prior to initiating the RA response;

c) be alert for the removal of RAs or the weakening of RAs so that deviations from a cleared altitude are minimized;

d) if possible, comply with the controller's clearance, e.g. turn to Intercept an airway or localizer, at the same time as responding to an RA; and

e) when the RA event is completed, promptly return to the previous ATC clearance or instruction or comply with a revised ATC clearance or instruction.

6.3.2 Controller responsibility during an RA

6.3.2.1 The procedures to be applied for the provision of air traffic services to aircraft equipped with ACAS shall be identical to those applicable to non-ACAS-equipped aircraft. In particular, the prevention of collisions, the establishment of appropriate separation and the information which might be provided in relation to conflicting traffic and to possible avoiding action should conform with the normal air traffic services procedures and should exclude consideration of aircraft capabilities dependent on ACAS equipment.

6.3.2.2 The controller procedures used during an RA are defined in the *Procedures for Air Navigation Services - Air Traffic Management* (PANS-ATM, Doe 4444).

6.3.2.3 Controller training programmes should include the following guidance. When a pilot reports a manoeuvre induced by an ACAS RA, the controller:

a) shall acknowledge pilots' reports of RAs using the phrase "ROGER";

b) shall not attempt to modify the flight path of any aircraft involved in the RA;

c) shall not issue any clearance or instruction to any aircraft involved until the pilot reports returning to the terms of the assigned ATC clearance or instruction; and

d) should provide traffic information if deemed necessary.

6.3.2.4 Once an aircraft departs from its clearance or instruction in compliance with an RA, the controller ceases to be responsible for providing separation between that aircraft and any other aircraft affected as a direct consequence of the manoeuvre induced by the RA. The controller shall resume responsibility for providing separation for all the affected aircraft when:

a) the controller acknowledges a report from the pilot that the aircraft is resuming the assigned clearance or instruction and issues an alternative clearance or instruction, which is acknowledged by the pilot; or

b) the controller acknowledges a report from the pilot that the aircraft has resumed the assigned clearance or instruction.

6.3.2.5 Controller training should emphasize that the use of ACAS does not alter the respective responsibility of pilots and controllers.

6.3.2.6 It is technically possible to provide controllers with information about ACAS RAs as they occur. In spite of the guidance given to flight crew, controllers should not assume that the pilot is obeying the RA. Nor should controllers assume that the RA information presented to them is current and correct, because ACAS can modify, and even reverse, the RAs, and there is an unavoidable delay in conveying RA information to controllers. The magnitude of the delay is dependent on the technical implementation of the system used for downlinking RAs.

[…]

6.3.4.5 In operation, the geometry that most frequently highlights the independence of ACAS thresholds from ATC separation standards is the 305 m (1 000 ft) level-off geometry. In this configuration, one aircraft manoeuvres in the vertical plane with the intent of levelling off on a FL 305 m (1 000 ft) apart from a level aircraft. When both aircraft are also in close horizontal proximity, and since the CAS logic does not know any pilot's intent, the vertical speed of the first aircraft can be sufficient to trigger an RA. In cases of altitude busts, this improves a hazardous situation. However, frequently both aircraft are (and should remain) separated in the

view of ATC, and this behaviour causes many RAs where there is no loss of separation. The number of such unnecessary RAs for 305 m (1 000 ft) level-offs can be reduced by separating vertical convergence from horizontal convergence through airspace changes or by slowing the vertical rates of levelling off aircraft either through procedural changes or through FMS flight profile changes.

6.3.5 Relationship between ACAS and short-term conflict alert (STCA)

6.3.5.1 ACAS and STCA algorithms were developed and operate independently of each other. ACAS has more frequent surveillance updates (once per second) than STCA. While STCA has more information than ACAS regarding an aircraft's intended flight path.

6.3.5.2 Operational experience has shown that there will be encounters in which the ACAS RA will be issued without an STCA alarm and that there will be encounters in which STCA alarms occur without an RA being issued. Controllers should consider ACAS and STCA as separate, independent systems.

6.3.5.3 Controller training programmes should address the interaction between ACAS and the STCA implementation at their workplace. This portion of the controller training should include replays and analyses of actual events where STCA, ACAS or both were triggered.

A-2. EU documents 923/2012

SERA.2010 Responsibilities

(a) Responsibility of the pilot-in-command

The pilot-in-command of an aircraft shall, whether manipulating the controls or not, be responsible for the operation of the aircraft in accordance with this Regulation, except that the pilot-in-command may depart from these rules in circumstances that render such departure absolutely necessary in the interests of safety.

Avoidance of collisions

SERA.3201 General

Nothing in this Regulation shall relieve the pilot-in-command of an aircraft from the responsibility of taking such action, including collision avoidance manoeuvres based on resolution advisories provided by ACAS equipment, as will best avert collision.

11 Appendix B. TCAS event related phraseology

after a flight crew starts to deviate from any ATC clearance or instruction to comply with an ACAS resolution advisory (RA) (Pilot and controller interchange)	*r) TCAS RA; s) ROGER;
... after the response to an ACAS RA is completed and a return to the ATC clearance or instruction is initiated (Pilot and controller interchange)	*t) CLEAR OF CONFLICT, RETURNING TO *(assigned clearance)*; u) ROGER *(or alternative instructions)*;
… after the response to an ACAS RA is completed and the assigned ATC clearance or instruction has been resumed (Pilot and controller interchange)	*v) CLEAR OF CONFLICT *(assigned clearance)* RESUMED; w) ROGER *(or alternative instructions)*;
… after an ATC clearance or instruction contradictory to the ACAS RA is received, the flight crew will follow the RA and inform ATC directly (Pilot and controller interchange)	*x) UNABLE, TCAS RA; y) ROGER

12 Appendix C. RA trigger by HVR event

PAN-OPS {DOC8168}

Attachment B to Part III, Section 3, Chapter 3

1.1 As of 2006, data collected by ACAS monitoring programmes continue to show that a large percentage of ACAS RAs are a result of climbing or descending aircraft maintaining a high vertical speed while approaching their ATC-assigned altitude. Changes have been made to the ACAS SARPs and guidance material (see Annex 10, Volume I) that have been effective in reducing the frequency of occurrence for these types of RAs, but these types of RAs continue to occur with a high degree of regularity in airspace throughout the world. It has been determined that no further changes are feasible within ACAS to address this issue without resulting in an unacceptable degradation of the safety provided by ACAS.

1.2 Modern aircraft and their flight guidance systems (autopilots, flight management systems, and auto throttles) are designed to fly specific flight profiles that provide fuel and time-efficient flight paths. An integral concept of the design of the flight guidance systems includes allowing an aircraft to quickly climb to higher, more efficient operating altitudes and to remain at these altitudes as long as possible, which results in descents also being made with high vertical speeds. For economic benefits, the high vertical speeds used in a climb or descent are retained as long as feasible before initiating a smooth capture of the aircraft's assigned altitude.

1.3 The design of the flight guidance systems can result in vertical speeds in excess of 15 m/s (or 3 000 ft/min) until they are within 150 m (or 500 ft) of the aircraft's assigned altitude. When a climbing or descending aircraft maintains a vertical speed in excess of 15 m/s (or 3 000 ft/min) until it is within 150 m (or 500 ft) of the aircraft's assigned altitude, it is less than 30 seconds away from being at the adjacent IFR altitude, which may be occupied by an ACAS-equipped aircraft flying level at that altitude. If the intruder aircraft is horizontally within the protected area provided by ACAS, there is a high probability that an RA against the climbing or descending aircraft will be issued just as the intruder aircraft begins to reduce its vertical speed to capture its assigned altitude.

Due to the operational impacts on pilots and controllers caused by these types of RAs, and the continued existence of these RAs and the constraints on further modifications to ACAS, operators should specify procedures by which an aeroplane climbing or descending to an assigned altitude or flight level with an autopilot engaged may do so at a rate less than 8 m/sec (or 1 500 ft/min) within 300 m (or 1 000 ft) of the assigned level. Such procedural changes should provide an immediate operational benefit to both pilots and controllers by reducing the occurrence of HVR RAs.

ACAS Manual{DOC9863}

In some airspace, a majority of RAs are unnecessary RAs generated when a climbing or descending aircraft levels off at an adjacent altitude to another aircraft, i.e. with 305 m (1 000 ft) of vertical separation. Research has shown that many of these RAs can be eliminated by airspace design that:

a) separates airways by 610 m (2000 ft) in geographic areas where aircraft will be levelling off in close horizontal proximity to other traffic; or
b) relocates the horizontal position where aircraft are levelling off to ensure adequate horizontal separation exists between aircraft.