APPROVED

Head of department

S.V. Pavlova

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GRADUATION WORK

(EXPLANATORY NOTES)

FOR THE DEGREE OF MASTER

SPECIALITY 173 “AVIONICS”

Theme: Marketing monitoring of the TCAS system and efficiency of its operation

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Kyiv 2021

МІНІСТЕРСТВО ОСВІТИ І НАУКИ УКРАЇНИ

НАЦІОНАЛЬНИЙ АВІАЦІЙНИЙ УНІВЕРСИТЕТ

ФАКУЛЬТЕТ АЕРОНАВІГАЦІЇ, ЕЛЕКТРОНІКИ ТА ТЕЛЕКОМУНІКАЦІЙ

КАФЕДРА АВІОНІКИ

ДОПУСТИТИ ДО ЗАХИСТУ
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ДИПЛОМНА РОБОТА
(ПОЯСНЮВАЛЬНА ЗАПИСКА)

ВИПУСКНИКА ОСВІТНЬОГО СТУПЕНЯ МАГІСТРА
ЗА ОСВІТНЬО-ПРОФЕСІЙНОЮ ПРОГРАМОЮ
«АВІОНІКА»

Тема: Маркетинговий моніторинг системи TCAS та ефективність її експлуатації

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Київ 2021

NATIONAL AVIATION UNIVERSITY

Faculty of Air Navigation, Electronics and Telecommunications

Department of avionics

Specialty 173 ‘Avionics’

APPROVED

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“___”_________ ___2021

TASK

for execution graduation work

V.O. Kutiepov

1. Theme of graduation work is the ’Marketing monitoring of the TCAS system and efficiency of its operation’, approved by order 1945/ст of the Rector of the National Aviation University of 22 September 2021.

2. Duration of which : 18 October 2021 to 31 December 2021.

3. Background to the work: Traffic Collision Avoidance System (TCAS), its principle of operation and expluatation.

4. Content of explanatory notes: List of conditional terms and abbreviations; Introduction; Chapter1; Chapter 2; Chapter 3; Chapter 4:;Chapter 5 :; Conclusions; References;

5. The list of mandatory graphic material: Schematic block-diagram of TCAS II, CAS logic functions block-diagram. Functioning of TCAS in the process of conflict resolving. Scheme of installation of TCAS system on aircraft.

6. Planned schedule

7.

№	Task	Duration	Signature of supervisor
1.	Validate the rationale of graduate work theme	18.10.2021	
2.	Carry out a literature review	19.10.2021 – 25.10.2021	
3.	Develop the first chapter of diploma	26.10.2021 – 02.11.2021	
4.	Develop the second chapter of diploma	03.11.2021 – 10.11.2021	
5.	Develop the third chapter of diploma	11.11.2021 – 18.11.2021	
6.	Develop the fourth and fifth chapter of diploma	19.11.2021 – 11.12.2021	
7.	Tested for anti-plagiarism and obtaining a review of the diploma	12.12.2021	

Consultants individual chapters:

Chapter	Consultant (Position, surname, name, patronymic)	Date, signature	
		Task issued	Task accepted
Labour protection	Ph.D., Associate Professor Kovalenko V.V.		
Environmental protection	Ph.D., Associate Professor Dmytrukha T.I		

ABSTRACT

Explanatory notes to masters degree work ‘Marketing monitoring of the TCAS system and efficiency of its operation’ contained 72 pages, 26 figures, 5 tables, 21 references.

The object of the research - Traffic Collision Avoidance System.

The purpose of the graduation work – is investigation of Traffic Collision Avoidance System (TCAS) market and efficiency of its operation.

Research Method – Monitoring the market of Traffic Collision Avoidance System (TCAS) and comparing systems from different vendors. Researching principle of TCAS operation and its components. Analising incidents, in which TCAS system was used to analize its efficiency.

Keywords: TRAFFIC COLLISION AVOIDANCE SYSTEM, RESOLUTION ADVISORY, AUTOMATIC DEPENDENT SURVELIANCE-BROADCAST.

CONTENTS

LIST OF CONDITIONAL TERMS AND ABBREVIATIONS

TCAS	Traffic alert and Collision Avoidance System
ACAS	Airborne Collision Avoidance System
CPA	Closest Point of Approach
ADS-B	Automatic Dependent Surveillance - Broadcast
PFD	Primary Flight Display
ICAO	International Civil Aviation Organization
SL	Sensitivity Level
FAA	Federal Aviation Administration
ATC	Air Traffic Control
FMS	Flight Management System
TA	Traffic Advisory
RA	Resolution Advisory
UAV	Unmanned Aerial Vehicles
FL	Flight Level
HMDF	Horizontal Miss Distance Filter
AGL	Above Ground Level
NMI	Nautical Miles
VSI	Vertical Speed Indicator
VI	Virtual Instrumentation

INTRODUCTION

70% of all incidents in aviations happenning after human operator made mistake. Traffic collisions are mostly happening after human mistke either by pilots or by air traffic controllers. After number of incidents in 1950s-1960s, concepts of Traffic Collision Avoidance System which abbreviated as TCAS was made. TCAS prevents collisions by warning about traffic in first place using Traffic Advisory (TA) mode and after intruder aircraft is closing by rapidly and distance is low it will give Resolution Advisory (RA) for pilots using commands for climbing or descending.

After mid-air collision in 1956 above the Grand Canyon aviation authorities with the help of airlines, started development of collision avoidance system. In the late 1960's and early 1970's, manufacturers were trying to make aircraft collision avoidance systems which used principle of operation based and relied on principle interrogator/transponder and also some of them made concepts based on time/frequency techniques. These systems functioned properly when tests were conducting by manufacturers during aircraft encounter testing, but FAA and the airlines have come into agreement that if that systems will be used in normal airline operations, the high rate of unnecessary alarms generated by the system in dense terminal areas will make impossible its operations. In the mid 1970's, the first collision avoidance concept called Beacon Collision Avoidance System was developed. BCAS used data received from the transponders of Air Traffic Control Radar Beacon System (ATCRBS) to determine other intruding aircraft's data about range and altitude.

TCAS Version 6.0 started to develop in 1980-s by FAA and was introduced in service in the United States during 1990s. In 1997 standard of Version 7.0 was approved and it started its operation in late 1999.

In the aftermath of incident in Japan in 2001 and mid-air collision in Überlingen in 2002, where TCAS command were issued, but pilots didn't follow them, main problem of TCAS system logic was found. TCAS II Version 7.1 was developed after that and added RA function known as RA reversal. It can give orders for pilots during following initial RA for changing evasion maneuver. TCAS version 7.1 became mandatory for installation on all aircrafts in Europe in 2013 for newly built aircraft and from 2015 all aircrafts, which flying in European airspace, must be equipped with Version 7.1.

Because of rapid growth of UAVs application are and increasing of numbers of them in the sky, the problem of its collision protection from civilian aircrafts arises. The main problem is that UAV don’t have pilots on board and that in most TCAS statndardts for its certification for use on-board of an aircraft, aircraft must be operating with pilots on-board.

TCAS systems are mainly made by following companies: Garmin, ACSS, Honeywell, Rockwell Collins.

“Marketing refers to activities a company undertakes to promote the buying or selling of a product or service. Marketing includes advertising, selling, and delivering products to consumers or other businesses.” [1]

“Management can be defined as the process of administering and controlling the affairs of the organization, irrespective of its nature, type, structure and size. It is an act of creating and maintaining such a business environment wherein the members of the organization can work together, and achieve business objectives efficiently and effectively.”[16]

“Aviation management does deal with logistics, finance, marketing, operations, commercial and revenue, and general human resource management regarding any aviation based company, but also looks into the public brand image, technical nature and maintenance management of aircraft and aircraft systems, just-in-time operations, scheduling problems, safety, security, national and international laws and regulatory framework.”[17]

The purpose of the graduate work is to investigate Traffic Collision Avoidance System (TCAS) market.

Following tasks should be done to achieve this purpose, the:

1. To analyse existing and proposed TCAS generations and its versions.
2. To analise principle of TCAS operation, its equipment, functions, logic of operation, collision avoidance concepts.
3. To analise TCAS systems vendors, their characteristics and properties, advantages of each system and their compatible aircraft.
4. To analise incidents, involving TCAS and show efficiency of its operation.

The object of the research is the Traffic Collision Avoidance System (TCAS).

The subject of the research is the market of TCAS systems.

Research Method - Monitoring the market of Traffic Collision Avoidance System (TCAS). Researching principle of TCAS operation and its components. Analising incidents involwing TCAS usage to show its efficiency.

CHAPTER 1
GENERAL OVERVIEW OF TRAFFIC COLLISION AVOIDANCE SYSTEMS, ITS PRINCIPLE OF WORK

Traffic collision avoidance system (TCAS) – it's an aircraft system, which was made to lower the chances of mid-air collision. It monitors surrounding airspace near aircraft, detects another plane, which equipped with TCAS transponder. If risk of collision is present, system warns pilots and recommends evasion maneuver. ICAO standards says, that TCAS must be present on aircraft, which heavier than 5700 kg or certified for carrying more than 19 passengers. Despite the TCAS implementation, mid-air collisions still have chanses to occur. Mostly it's because of mistake from pilots, who didn't obey TCAS orders, because it only can give the pilots recommendation and can't control working of autopilot. Only pilot can avoid collision while using TCAS recommendations and visual observation.

1.1. General overview of traffic collision avoidance system

The problem of an aircraft collision in the air started in time when aviation itself. The first mid-air collision, which was recorded, was at "Milano Circuito Aereo Internazionale" meeting on 3 October 1910 in Milan, Italy. Despite the air seems infinite for aircraft, it was always full with planes in the air. Crowdness in the air become very obvious when civil jet fleet started rapid development.

The problem of air traffic collision during flight became known clearly in the 50s. When air crashes with big number of casulities started to happen, ICAO (International Civil Aviation Organization) started to adress this issue. Was developed base concepts and the international standards of the Airborne collision avoidance system (ACAS).

In accordance with concepts, the TCAS (Traffic alert and Collision Avoidance System) system was issued.

The system (latest version and modified version) observes the airspace around the aircraft, detects all other aircraft, analyzes the information received, transmits it to the crew, warns pilots and immediately takes some action in the event of a collision hazard.

Currently, the latest version of the system is TCAS II. In the past, there was a so-called passive surveillance system that did not actively check the airspace, but used signals from other aircraft to satisfy requests from the ground or other aircraft systems.

Then the TCAS I system was developed, which can analyze air conditions within 30 miles and provide the crew with general information (altitude and flight direction) about other aircraft movements. The system can only issue a TA (Traffic Advisory) signal to warn another aircraft of an approaching flight.

However, at present, only TCAS II is fully compliant with ACAS standards. It is currently installed on most commercial aircraft. It is produced by the following companies: Rockwell Collins, Honeywell and ACSS. [2]

1.2. Versions of Traffic Collision Avoidance System and further ways of its development

1.2.1. Passive

A passive collision avoidance system based on the response of the transponder can be triggered by ground and air systems. Ground and air interrogators request mode C altitude information in neighboring transponders, and third-party systems can track this information to obtain traffic information. The passive system indication on the display is similar to TCAS, but usually has a range of less than 13 kilometers. [3,18]

1.2.2. TCAS I

TCAS I was the first generation of TCAS. It observes traffic conditions within a distance of approximately 65 kilometers and provides with information about the approximate altitude and heading of other aircraft. It generates a collision warning in the form of a traffic announcement (TA). TA warned always the pilot to pay attention to another aircraft in the danger zone and declared "move, move", but did not advise the pilot to take some action to avoid a collision. Pilots usually need to take countermeasures with the assistance of air traffic controllers. When the threat disappears, the system will report "Conflict Resolution".[3,18]

1.2.3. TCAS II and its versions

TCAS II is the first TCAS system and it was put into use in 1989 being the current generation of TCAS and the most widely used version of TCAS. The first aircraft to be certified by AlliedBenda (now Honeywell) TCAS II was the US Airways B737. It performs the same functions as TCAS I, but also provides pilots all other with direct instructions to avoid dangerous situations, called problem solving recommendations (Ra), which can be visual or audible. The proposed action may be a "correction" that can cause a change in vertical speed. The following commands are used to notify the pilot of "descent, descent", "up, ascent" or "vertical speed control correction". "(Slow down.) An RA may be issued to warn pilots not to deviate from their current vertical speed, and announcing "control vertical speed" or "keep vertical speed and stick to it." TCAS II coordinated the pilot to execute the prompt command to issue instructions. When an aircraft is instructed to descend, it usually orders another aircraft to climb, thereby increasing the distance between the two aircraft. [3,18]

Three versions of TCAS II are currently running:

• Version 6.04a is still approved for some aircraft operating in US airspace. In Europe, version 6.04a can be used on aircraft that are not covered by current European approvals (such as military, understaffed, or passenger seats). Version 6.04a does not can have comply with the ICAO ACAS SARP (Annex 10, Volume IV).

• Version 7.0 is still approved for use on most aircraft in the United States and around the world. Version 7.0 is the first ICASO SAS version in TCAS II that meets ACAS requirements (Appendix IV, Appendix 10); however, as of 2010 (Revision 85), it is only compatible with version 7.1. In Europe, version 7.0 can be found on aircraft that are not covered by the current European license (so it can be on military or mandatory cargo or passenger seats).

• Version 7.1 is the only ACAS version that complies with current ICAO and European regulations. It solves two security problems based on the improved performance analysis of version 7.0. [4]

After the mid-air collision of Überlingen (July 1, 2002) and the attempted incident of Japan Airlines over Suruga Bay, version 7.1 was developed to improve TCAS II functions. Therefore, by 2008, TCAS II 7.1 version of the standard has been published and published as RTCA DO-185B (June 2008) and EUROCAE ED-143 (September 2008).

TCAS II version 7.1 can always issue RA commands in case one of the conflicting aircraft does not follow the original RA commands. One of the updates of version 7.1 is to replace the "Adjust vertical speed, adjust" RA command with the "Level off, Level off" RA command to prevent the pilot from responding improperly. And when the positive RA is weakened only due to extremely low or high-altitude conditions (1000 feet or less above the ground, or close to the top ceiling of the aircraft), the corrective/preventive notice and improvement of the green arc display to prevent errors and possibilities Guidance of the danger to the pilot (change proposal CP116).

Version 7.1 has been mandatory for new aircraft in Europe since March, and will be mandatory on all aircraft by December 2015. Version 7.1 contains the changes caused by the Uberlingen 757 and Tu-154 air collision in July 2002. Internationally, the International Civil Aviation Organization recommends that version 7.1 be installed on new aircraft from January 2014 and on all aircraft before December 2017. [4]

Eurocontrol research shows that the probability of mid-air collision occurrence in European airspace is once every 3 years. [3,18]

1.2.4. TCAS III

TCAS III was originally made conceptually under the name TCAS II Enhanced and is considered an extension of the TCAS II concept, including recommendations for horizontal resolution. TCAS III is a next-generation collision avoidance technology researched by companies such as Honeywell. TCAS III includes technical updates to TCAS II, which can use horizontal and vertical maneuver guidance to provide pilots with traffic guidance and collision problems. For example, in an oncoming situation, one aircraft may be instructed to "turn right and climb", while another aircraft will be taught "turn right and descend". This helps to further increase the overall gap between the horizontal and vertical planes. When two aircraft collide close to the ground, the horizontal direction is useful, but there is almost no room for maneuvering in the vertical space.

TCAS III can use TCAS information from directional antennas to create horizontal maneuvers by assigning directions to other aircraft. However, the industry had calculated information that this cant be used because TCAS directional antennas limited accuracy. A directional antenna is determined to be not precise enough to provide very accurate spatial horizontal position and accurate horizontal resolution. Due to years of testing and analysis up to 1995, there was insufficient information about the horizontal position, making it impossible to implement this concept using existing monitoring methods, and in most cases. It could not be determined that horizontal RA was not used for collision geometry. All TCAS III work has been suspended and there are no implementation plans. This concept has been constantly evolving and has been replaced by TCAS IV. [3,18]

1.2.5 TCAS IV

TCAS IV uses the additional new other information that the target aircraft encodes the position of the transponder signal in the S-mode transponder response to generate the horizontal resolution of the RA. Also, the target aircraft needs dependable location sources for encoding (such as inertial navigation systems and GPS).

TCAS IV had replaced the concept of TCAS III by the mid-1990s. The main result of the TCAS III experiment is a safe horizontal resolution because the directional antenna used by the TCAS processor to assign the direction of the received transponder response is not accurate enough. Directional antenna accuracy is not important because TCAS IV uses additional position information encoded in the aerial data line to generate directional information.

Although the development of TCAS IV has been underway for several years, it is necessary to confirm the existence of communication systems with the emergence of new trends in data transmission channels such as ADS-B (Automatic Dependent Surveillance Broadcasting). TCAS IV must be used in more regular air-to-air data transmission systems for upcoming use. Due to these problems, the construction of the ADS-B system was started, and the development of TCAS IV was discontinued. [3,18]

1.2.6 ACAS X and its versions

The ACAS X warning logic uses a set of hard-coded rules for the system, and also is based on an airspace probability model and many safety and operational optimization lookup tables.

The probability model provided by ACAS X contains a statistical representation of the future position of the aircraft. It also takes into account system safety and operational goals so that the logic can be adapted to specific procedures and airspace configurations.

An optimization process called dynamic programming is introduced and can be used for determination the best solution in a competitive environment. In this case, use the fee and collection system to determine which transaction is the most profitable (ie, if effective evasive operations are performed, safe separation can be guaranteed). An important indicator of pilot availability and agreement is to minimize the frequency of warnings. This can reverse/intentionally increase the height of the attacker or make destructive suggestions in the event of a minor collision. The real-time lookup table is used for solving conflicts. ACAS X collects inspections from multiple points of origin (almost every second). Various models can be used to estimate the state distribution, that is, the probability distribution of the aircraft's current position and speed (for example, a probabilistic sensor model that considers sensor error characteristics). State decomposition determines where to look in the digital lookup table to decide the best action (including the "do nothing" option). If demanded, the pilot will receive recommendations for approval.

With the introduction of ACAS X we can achieve following improvements:

Decreasing number of unnecessary information: TCAS II is very sistemized system that runs on a schedule. However, a warning will be displayed even if the aircraft is moving safely.

It is flexible for operation of future concepts: SESAR and NextGen are working to implement new running ideas to decreas the separation in space between aircraft. The current format of TCAS II is obsolete because its is can’t be runned with these concepts, is used frequently, and has many false suggestions.

Advanced collision avoidance vorking operation principle in various aircraft categories. To obey following recommendations limiting for TCAS II to meet aircraft categories knowing following that can meet certain performance standards (for example, 2500 ft/min is required minimal vertical speed). This does not include many used aircrafts in civilian general aviation (GA), usage on all unmanned aerial vehicles (UAV) or distant remote controlled aircraft systems.

Use the monitoring environment of the future. Both SESAR and NextGen are looking to implement new surveillance sources, especially satellite-based navigation and advanced ADS-B capabilities. But, TCAS II only relies on the transponder installed on the aircraft, limiting its flexibility to take advantage of these advancements.

Enhanced security; ACAS X is expected to be more secure while reducing unnecessary warnings.

The system with usesage of the same equipment (antenna and display) as the TCAS II and the same direct access range as the TCAS II version 7.1. In addition to maintaining the RA's vertical and horizontal vertical speeds, the information displayed to the RA and the pilot remains unchanged. The ACAS Xa tuning uses the same auditory information as the up or down RA, or the reverse up or down RA (if the RA that supports the vertical rate is a reverse RA). Therefore, pilots and controllers can’t feel the different in changes with the current TCAS II system (version 6.04a, 7.0, and 7.1), and will not feel the difference in the changes brought about by the transition to the new system. As time goes by, ACASXa will replace TCASII.

The ACAS Xa first standards (EUROCAE ED-256 and RTCA DO-385) was finished in September 2018, and it is planned that ACAS Xa will be introduced into commercial use after 2020.

ACAS Xo-The ACAS X extension is proposed for specific tasks especially for a closely spaced parallel approach. The ACAS Xa system is not suitable as it produces many false alarms. The standard is planned to be ready in 2020.

ACAS Xu is proposed extension of ACAS X, designed for operation in remote control systems (RAS), including horizontal resolution operation. The standardization work will begin in 2016 and expected to be completed in 2020s.

ACAS Xp-A version of ACAS X uses only passive ADS-B to track intruders and does not actively investigate. It is intended for use in general-purpose aircraft (GA does not currently require installation of TCAS II). [19]

1.2.7. TCAS on UAV

Since TCAS has already been developed and put into use, it may bring short-term safety benefits to drones. The requirements for equipping large UAVs with TCAS have been formulated to improve safety of operations and satisfy FAA Directive 7610.4. The drone operator can control the vertical speed so that it can provide TCAS flow and RA display to the operator so that they can perform traffic avoidance operations to comply with TCAS RA. Hovever, the question is whether such operations are safe or not.

There are some safety concerns about equipping drones with TCAS. The UAV was not originally taken into account by ICAO when considered various TCAS and ACAS tasks. Although many drone models exceed the weight requirements of the ACAS II equipment, the drone TCAS is not intended to be part of the ICAO obligations. Since all safety investigations conducted to certify TCAS are based on the assumption that the pilot will be on the plane, TCAS has the advantage of improving situational awareness and assisting in visual searches of air traffic. Situational awareness is different from the application of manned aircraft, because there are no pilots on the drone to observe the outside of the aircraft. Due to the wrong direction of TCAS and the update rate, FAA and ICAO stated that TCAS display alone is not enough to provide operators with sufficient situational awareness to avoid threats. The inability to perform visual capture means that the drone operator cannot confirm the traffic display information. Therefore, the certification authority is concerned about its use.

In addition, TCAS works by querying the transponders of equipped aircraft, so TCAS does not track traffic aircraft without transponders. Aircraft only need to be equipped with transponders which reports altitude in Class A, B, C airspace and Class E airspace over 10,000 feet. At low altitude Class E and uncontrolled airspaces where drones usually fly, TCAS cannot detect unequipped intruders. Currently, drone pilots cannot visually capture these types of threats.

It is also known from practice that the pilot’s late response to the information from resolution recommendations will lead to a higher risk of collision compared to the case without TCAS. Due to the cross-border nature of the long-range UAV control modes at this location, there may be some communication delays between the aircraft and the ground pilot. If the pilot orders the aircraft to perform evasive operations, this will delay the response to the RA and reduce safety.

Another option under consideration is to equip the UAV with TCAS in TA-only mode, rather than equipping the UAV with a TCAS II system which can be used for generating RA collision avoidance recommendations. It is being discussed to equip UAVs with TCAS in TA-only mode, as pilots do not have the right to react solely to TAs and have no ability to visually capture threats.

Another option is to allow TCAS to control the drone and perform avoidance operations automatically. This level of automation effectively frees UAV pilots from the collision avoidance process. It has been shown that the level of safety delivered by TCAS improves with how accurate and consistent RA responses were. If system failure is abscent and information, which is avaible for operators, is perfectly accurate and complete, every time an RA is issued, an immediate and correct TCAS response will be used to improve security. TCAS has not yet been integrated into the autonomous driving system and has not passed autopilot response certification.

More recently, as a topic of discussion at a recent ICAO Monitoring and Conflict Resolution Systems Expert Group (SCRSP) meeting, the steps required to assess TCAS performance in UAVs have been further explored. Initial development of TCAS required a lot of testing, processing of information, simulation and operational evaluation. It costed US $ 400 million in fiscal year 2001. It is clear that UAVs have not yet made such developments and require rigorous efforts to determine the requirements and procedures required to perform TCAS on UAVs. Prior to this, following the recommendations of the International Civil Aviation Organization, the safest way to operate a drone on a NAS is to equip it with an altitude report 25-foot mode S transponder. Additional research and testing requests by funding UAV TCAS safety studies recommended by the International Civil Aviation Organization. In addition, a flight test must be conducted to evaluate the performance of the TCAS aerial drone.

Figure 1.1. Concept of the TCAS display on UAV

1.3 TCAS II components and its principle of operation

1.3.1 TCAS II components

The block scheme for TCAS II system in the aircraft is shown in Figure 1.1. The TCAS II system consists of the main components of the TCAS computer unit, S-mode transponder, S / TCAS-mode control panel, antenna, and cockpit demonstration.

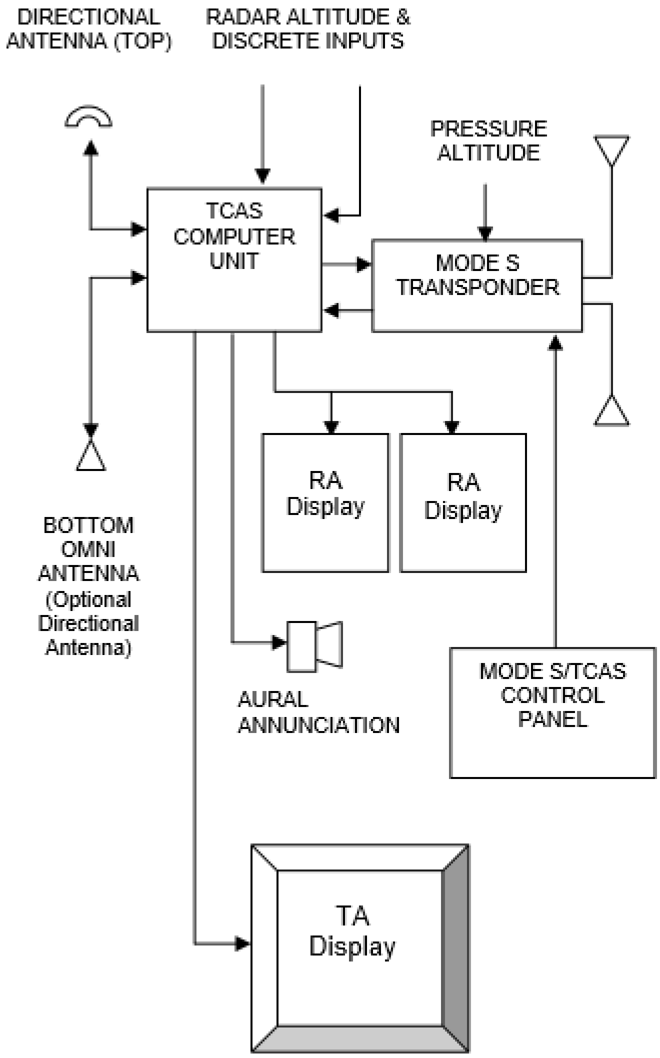


Figure 1.2. TCAS II Block Diagram

The TCAS computer unit is also can be called as the TCAS processor and performs tasks used for airspace monitoring, tracking of intruders, area of own aircraft height tracking, threat detection, RA decision making and recommendations. The TCAS processor processes data from sensors which equipped on its own aircraft (radar altitude, barometric altitude, and individual aircraft status inputs) to control the principle determined collision avoidance parameters for secured spaces around TCAS. If the followed aircraft chooses to avoid the aircraft in flight, there is sufficient vertical misdistance between it and the intruder, and changes to the existing flight path are usually minimized. If the treatment device is also equipped with TCASII, the preventive operation will be coordinated with the treatment device.

TCAS II requires an S-type transponder to be installed and must be usable. In case of mode S signal communication fails, the TCAS operational monitoring will anknowladge this fall and automatically will shift TCAS to standby mode. The S-mode transceiver uses the function that usually supports ATC in the air, and is used in conjunction with the basic model of ATC RBS or S-mode. S-mode equipped modules are used to provide air communication with two TCAS-equipped aircraft. You can edit other RAs as needed.

A TCAS control panel is included, including the next elements: a TCAS CPU, transceiver of S mode operation, and in spetial conditions, a TCAS display. Usually, operational panel provides four (4) basic control modes and allows the crew operation of all following TCAS functions:

Standby: The TCAS processor and Mode S transceiver are powered, hovever TCAS can't produce a demand and the interviewer gives only some premade specific instructions. The transmitter is still emitting a peak signal. If the aircraft is on the ground and you are sending text messages forward, you do not need to send many text messages.

Transponder: In this example, TCAS still uses standby mode. S mode transceivers works live and respond to all TCAS inquiries.

TA only: transponder mode is fully functional. TCAS is working normally and performs all tracking functions and issue interogations. RA provided

Auto or TA/RA: The S transceiver is turned on and usable. TCAS operation is proper. TA and RA are issued by TCAS as needed. As we can see information from Figure 1.2, all TCAS control signals pass through an S-mode repeater.

TCAS II antennas consists from directional antennas installed on the top of the aircraft and from some directional or omnidirectional antennas equiped on the bottom of the aircraft. Directional antennas are usually installed at the bottom of the aircraft.

These antennas operate at frequencies of 1030 MGs at different power levels for each 90-degree directional section. The lower antenna sends out a lower signal with less power input than the upper antenna installed. The carrier also receives the response at 1090MHz and sends the response to the TCAS processor. Antenna control reduces garbled syncopated characters.

Additionally, for dual TCAS antennas, there are used two extra few antennas for working S-mode transceivers. One of the antennas is installed on the top of the aircraft, and the other is installed on the bottom. These antennas included into the S transponder mode, which capable of receiving signals with a frequency of 1030MHz and a response frequency of 1090MHz. Automatically select the appropriate antenna for controlling the signal power and reduce multipath interference. The new TCAS transponder system will incorporate further two antennas, which are only common to the transceiver and TCAS.

Since the transmitted signal of each TCAS module and transponder has the same operational frequency as another receivers, the TCAS and further transponder are connected to the aircraft's funnel bus and separate when other modules send signals. [5,21]

1.3.2 Cockpit Presentation and commands

The TCAS interface is showed by two displays in the cockpit: the RA display and the traffic display. These two screens can be installed in different forms, including merging of two screens. Regardless of the implementation, the same information is provided.

Traffic view can only be done on a part-time or full-time basis. The traffic information display also includes a vertical speed display. The main purpose of the motion indicator is to help the crew in the summer to visually identify the aircraft. The second purpose of the motion indicator is to ensure that the crew are confident in the correct operation of the system and give them time to prepare the aircraft in the event of an RA problem.

In the instance of part-time use, once the TA or RA is issued, the discount will be automatically activated. Existing applications use dedicated screens for traffic; display traffic information on general weather radar displays, map displays, engine and crew displays, navigation (ND) displays, and other displays, such as cabin traffic combined with automatic control broadcast surveillance (ADS) Information Display (CDTI) -b).

Most traffic monitors also permits pilots to select multiple zones and specify an altitude range for displayed traffic. These abilities helps the pilot to view traffic while cruising long distances and at higher altitudes, while keeping the lower viewing areas wide in the peripheral areas to decrease the amount of viewing interference.

Figure 1.3 shows the different passcodes. Its notable that TCAS/CDTI have default shapes and colors. TC and RA don’t have changes. [5,21]

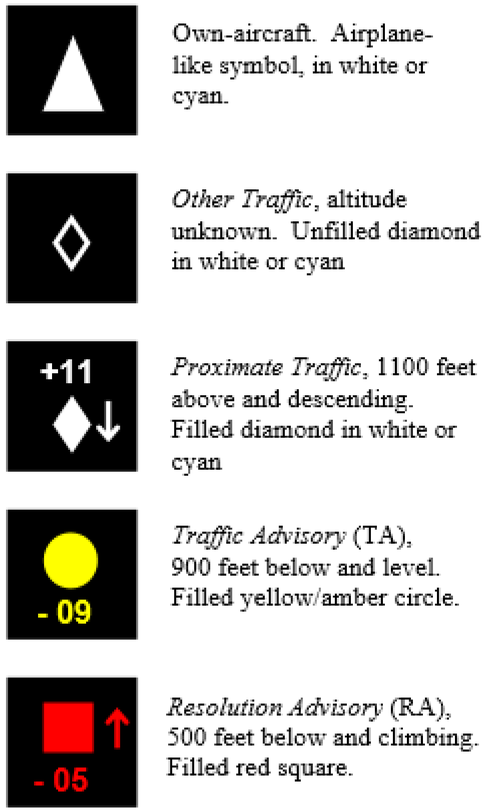


Figure 1.3. Standardized Symbology for Use on the Traffic Display

Colors and shapes are used to help the pilot interpret the displayed information. Your plane displayed as white or cyan airplane-like icons. The position of the your jet icon on the screen depends on the realization of the display. Other aircraft use geometric symbols to describe the threat situation, as shown below.

An unfilled diamond that appears cyan or white but is not the same color as your jet icon is used to represent "other" traffic that is free of threats.

Filled diamonds, appearing cyan or white but not the same color as the special level icon, are used to represent approximate traffic. Nearby traffic is threat-free traffic within 6 nmi and 1,200 feet from your plane.

A filled yellow or amber circle indicates the intruder plane for which the TA was issued.

The filled red square indicates that the RA intruder plane is used to display the RA intruder.

At some point in the process, the traffic you see can be different. When a TA or RA occurs, the TA, RA, and proximity traffic must be displayed within the specified display range. It is recommended to view other traffic to help pilots acquire the visible intruders that cause RA or TA. Pilots can derive an approximate state of traffic from relative distance and altitude, and symbol indicators allow them to consciously determine this state at a glance.

The colors and shapes are used to explain the information displayed to the pilot. The level is displayed as a white or blue icon, just like a level. The position of the flat icon on the screen depends on the design of the screen. Other airplanes are depicted by geometric symbols in accordance with the emergency state as follows.

An unfilled blue or white diamond, but in a different color than the aircraft symbol, it is used to indicate other non-hazardous traffic.

Full or white diamonds that are different from the color of the flat surface are used to show the approximate flow. The closest move is a safe move at distances of 6 nm and 1200 feet from the aircraft.

An amber or yellow circle indicates the intruder who caused the TA.

The filled red area indicates that the intrusion surface caused the release of RA.

During operation, the flow rate at different times is displayed differently. DuringTA or RA initialization, you need to display TA, RA, and adjacent traffic within the specified display range. Other traffic checks are recommended to assist the pilot in visually catching the intruder responsible for the RA or TA. The pilot can infer how close the traffic is to the relative distance and altitude, and the display of the icon allows the pilot to perceive and confirm this situation at a glance.

The traffic display contains a designated full-scale distance marker so that the pilot can determine the distance to the displayed aircraft. Each icon is displayed on the screen according to the relationship with the aircraft. In some interpritations of the display, additional frequency band allocations in a narrower range, such as 2 nm, may be provided. The selected display range is also shown on the screen. Distance markers and distance messages are displayed in the same color as the airplane icon. However, unless you are using the traffic view in combination with an existing screen that already has a distance marker (such as a MAP monitor).

If the intruder is above your aircraft, the relative altitude is displayed hundreds of feet from the icon, and if the intruder is below your aircraft, it is displayed below the icon. If the intruder is on your plane, the information about the relative altitude will be preceded by a + sign. If the intruder is under the plane, the relative altitude will be displayed before the “-” sign. On some aircraft, the height of the intruder may be displayed instead of the relative height of the intruder. The intruder is on your plane, and the intruder is under the traffic sign below your plane. If the intruder does not report his height, the information on the traffic light will not be displayed. Altitude information is displayed in the same color as your aircraft.

As the target aircraft reports altitude and climbs or descends at speeds above 500 feet per minute, to the right of the traffic icon an arrow will appear. The up arrow is used to indicate the climbing plane. The down arrow is used to indicate a downgrade. The arrows are displayed as airplane symbols of the same color.

When the level causing TA or RA exceeds the currently set traffic display area, half of the TA or RA icon will be displayed in the corresponding relative direction along the edge of the screen. In some cases, when the intruder is outside the specified view area, or the selected view does not support streaming view, information such as 'traffic', 'TCAS' and 'TFC' are shown to view the stream. If the traffic does not move within the specified display area, a half-character or typed message will be displayed. The pilot either expands the view into a variable area so intruders can be seen, or chooses a view mode that can show traffic conditions.

The direction information is used only for signaling purposes, so the lack of direction information does not affect the TA and RA versions of the TCAS feature. If no TA or RA loader is issued, the intruder threat level, range, relative altitude and vertical speed will be displayed on the traffic screen. This text is displayed in red for RA and yellow for TA. For example, if an intruder with a distance of 3.5 nmi and a relative height of +1500 ft or less issues RAs in descending order, the traffic screen will display the message "No Bearing". RA3.5 + 12

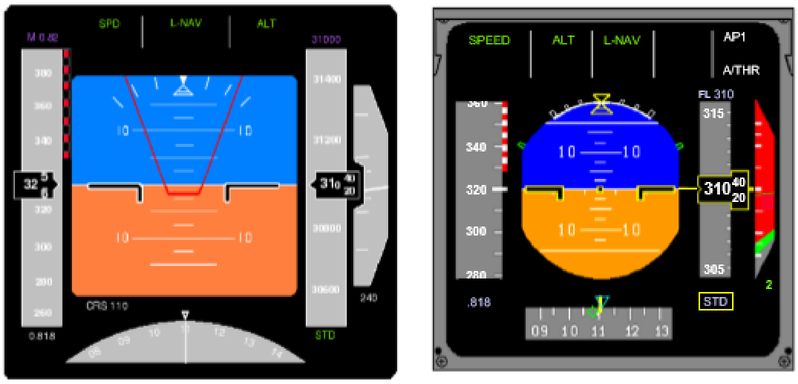
RA monitors provide experimental data on vertical speed or pitch angle to prevent or avoid collision accuracy. RA monitors are usually equipped with an instantaneous vertical speed indicator (IVSI). This is the step marker that appears in the vertical speed range as part of the basic flight display (PFD). The RA manual also applies to head-up displays (HUD). Applications with IVSI or vertical speed bars use traffic lights or signals to indicate the vertical (red) speed to avoid and the (green) vertical speed required for flight. Applications that use step markers use the unique shape of the PFD to indicate the pitch angle to move to avoid or resolve collisions. The HUD app also uses unique shapes to show the path of flight or collision avoidance.

IVSI disk applications are commonly used on older "non-glass cockpit" aircraft. However, some airlines use this screen on Glass Cockpit aircraft and use it as a common indicator for all types of fleets. Some IVSI additionals use mechanical instruments with red and green LED indicators around the screen, while others use LCD screens to put the red and green arcs in place Create By installing an LCD screen, you can check the flow rate and RA at 1 meter.

For glass cockpit aircraft with PFD, some aircraft manufacturers have RA displays on their vertical speed indicators, some choose to send pitch signals, while others provide pitch signals and vertical speed indications.

On Figure 1.4 the RA display installed on the LCD screen is seen which also can provide traffic information. Figure 1.5 displays two possible actions in the PFD. [5,21]

Figure 1.4. TCAS RA Display Implemented on an IVSI



Pitch Cue Implementation **Vertical Speed Tape Implementation**

Figure 1.5. TCAS RA Displays Implemented on a PFD

On Table 1.1 types of RA and TA commands and required actions are shown

Table 1.1. Types of traffic and resolution advisories

Type	Text	Meaning of command	Required Action
TA	*Traffic; traffic.*	Intruder near both horizontally and vertically.	Attempt visual contact, and be prepared to manoeuvre if an RA occurs
RA	*Climb; climb.*	Intruder will pass below	Begin climbing at 1500–2000 ft/min
RA	*Descend. Descend.*	Intruder will pass above.	Begin descending at 1500–2000 ft/min
RA	*Increase climb.*	Intruder will pass just below	Climb at 2500 – 3000 ft/min
RA	*Increase descent*	Intruder will pass just above	Descend at 2500 – 3000 ft/min
RA	*Reduce climb*	Intruder is probably well below.	Climb at a slower rate
RA	*Reduce descent*	Intruder is probably well above.	Descend at a slower rate
RA	*Climb; climb now*	Intruder that was passing above, will now pass below.	Change from a descent to a climb
RA	*Descend; descend now*	Intruder that was passing below, will now pass above.	Change from a climb to a descent
RA	*Maintain vertical speed; maintain*	Intruder will be avoided if vertical rate is maintained.	Maintain current vertical rate
RA	*Level off, level off*	Intruder considerably away, or weakening of initial RA.	Begin to level off
RA	*Monitor vertical speed*	Intruder ahead in level flight, above or below.	Remain in level flight
RA	*Crossing*	Passing through the intruder's level. Usually added to any other RA	Proceed according to the associated RA
CC	*Clear of conflict*	Intruder is no longer a threat	Return promptly to previous ATC clearance

1.3.3 TCAS target survelliance functioning

TCAS monitors nearby aircraft regardless of ground input, provides information about the location and altitude of these aircraft, and enables collision avoidance algorithm functions. The principle of operation of the TCAS monitoring function is to issue a request at a frequency of 1030 MHz, with the nearest transponder of the aircraft responding to the request at a frequency of 1090 MHz. These responses are received and decoded by the TCAS monitoring software as part of the TCAS software, and the information is sent to the collision avoidance algorithm.

It is expected that TCAS will provide reliable monitoring with a traffic density of 0.3 aircraft per square nautical mile and a distance of up to 14 nautical miles. The monitoring algoritms supplies information about coverage, altitude, range, and direction for nearby aircraft to achieve collision avoidance, identify intruders, and make the information displayed on the traffic screen accurate. The TCAS controller is compatible with Model S and ATCRBS transceivers. TCAS can simultaneously discover up to 30 aircraft equipped with transponders with a nominal range of 30 nm.

One of the requirements of the TCAS system is that it does not interfere with the operation of the ATC radar, since the TCAS monitoring operates at the same frequency used by the ground-based ATC radar. Various design features have been developed and implemented to enable TCAS to provide reliable surveilance without affecting the performance of the air traffic control radar.

The mode S selective addressing system makes it relatively easy to monitor TCAS on a mode S-equipped aircraft. TCAS listens to the automatic transmission or scatter generated by the Mode S repeater once per second. In particular, the recoil position has a unique S position address for the sending aircraft. The S-mode address is known as the 24-bit address of ICAO aircraft worldwide.

After receiving and decoding the aircraft message, TCAS sends a request signal in S mode to the S-mode address of the aircraft message. These queries are typically generated every second. International standards require that the request be sent at least once every 5 seconds. S-type transceivers reply to these requests, and TCAS uses this response data to determine the distance, direction, and altitude of the mode S plane

In order to reduce the interference of the 1030/1090MHz channel on other aircraft and air traffic control, the speed at which TCAS sends a signal to the Mode S aircraft depends on the stopping speed and speed of the two aircraft. In case of long distances, the target is called every 5 seconds. When the intruding aircraft closes for an area where TA may be required, the request frequency is increased to once per second.

TCAS monitors each target's distance and altitude in S mode. These messages are secured by collision avoidance logic and are used to detect traffic and advise logic. The respective orientation of the target is also provided by the anti-collision logic used in the horizontal scroll filter to correctly display the intruders position on the traffic display.

To query the A / C mode transmitter, TCAS uses a changed C mode request called a mode C only call. The nominal required frequency of these transponders is once per second.

The TCAS relay code for the nearest aircraft A mode code is not recognized by TCAS because TCAS does not use mode A requirements.

If the aircraft don’t have installed with a generic altitude encoder and there is no data in the response altitude field, the sensor will need to respond to these requests. To provide and continue to maintain distnance and direction specified purposes, TCAS uses frame response pulses. Similar to S mode trucks, these responses transmitted to collision avoidance logic to identify, select, and display traffic advisory recommendations.

The response of an aircraft that can provide altitude in C mode is tracked by range, altitude, and azimuth. These messages are transmitted to TCAS logic to identify TAs and RAs and allow them to see nearby traffic on their traffic screens.

Due to synchronization and asynchronous distortion issues and signal reflections from the ground (reusable), monitoring TCAS targets in Mode C becomes complicated. If TCAS only sends a request for all Mode C calls, all Mode C responders who recognize the request will reply. Due to the extent of the response message (20.3 μs), aircraft with all C modes will respond within a range of 1.7 nm from the TCAS plane. When received by TCAS, the response will be distorted or overlapped. This is called Synchronous Cloud. TCAS includes multiple methods to handle this situation.

The hardware devices can analyze and decode three partially overlapping responses. In addition, the combination of the required energy level and the variable demand of the decay pulses reduces the number of repeaters responding to a single request. This method, called Whisper-shout (WS), takes advantage of the difference between the sensitivity of an aircraft's transceiver and transmitter antennas.

The first step in the WS sequence consumes low power. The next WS process sends the damping pulse first at a level slightly lower than the first request. The damping pulse follows the requirement for a slightly higher energy level after microseconds. This action blocks most repeaters who repeated to the other request, but received a response from an additional set of repeaters who did not respond to the previous request. To divide the response of the WS action into groups and reduce the probability of a reset, the WS procedure is performed in 24 consecutive steps. Fewer WS order chains are used on both sides and directions of the feed. WS sequences are sent once per watch refresh period, typically 1 second.

Another way to reduce synchronization distortion is to use vectorial transmission to further reduce the amount of potential interaction. To provide 360 degree coverage, slightly overlapping coverage should be provided in all directions. Simultaneous distortion is reduced only in mode c. With this request, the mode S responder cannot respond to the mode C request.

Asynchronous clutter is based on undesirable transponder answers in response to ground sensors or other TCAS requests. These so-called responses are short-lived and are usually identified and rejected by the algorithms associated in the monitoring logic. The TCAS experiment showed that a pathway was very unlikely to be found and maintained based on fruit observations.

Another important piece when designing TCAS monitoring is to avoid inducing monitoring effects based on multipath responses. Multiple paths from the same plane usually have less bandwidth and generate multiple responses to the same request. This is due to reflex studies and usually occurs on flat ground. The multipath control front load power level is used to raise the minimum trigger level (MTL) of the TCAS receiver. This is enough to distinguish between delayed energy reflections and low power reflections. The 4-pulse direct response is above the DMTL level, while the low power multi-channel delay response is unnecessary for the TCAS.

Interference reduction is fundamental surveilance function. Multiple TCAS modules check each other to ensure that TCAS will not inhibit transmissions higher than 2%, and TCAS will not produce an unacceptably high success rate on the ATC ground radar. Transmission under certain conditions. With the increase in the number of TCAS modules in this field, it is necessary to reduce the frequency and power allocation required by each TCAS module to prevent unnecessary interference to ATC radars.

eEach TCAS block monitors the number of other TCAS groups in the monitoring area. This can be achieved when each TCAS unit periodically (every 8-10 seconds) sends a TCAS broadcast message containing the S-mode address of the transmitter. The host TCAS interference mitigation algorithm then uses these reports to develop a large number of aircrafts with TCAS-equipped NTAs. Each TCAS NTA will be used as needed to limit the speed and execution of requests.

Interference suppression has been an integral part of TCAS from time when it was developed, but first-time use of TCAS shows that monitoring design needs to be improved to meet requirements. Starting from version 7.0, three changes have been made to limit the damage from the interference.

(1) In addition to finding the number of adjacent TCAS aircraft, each TCAS must also calculate the distribution of adjacent TCAS aircraft. This allows the algorithm to take into account the difference in the distribution of TCAS aircraft on the road and in the station's illuminated areas.

(2) The interference reduction algorithm is simplified for TCAS-equipped aircraft at a flight altitude of 180 (FL) to provide a longer field of view for aircraft flying in heavy traffic areas.

(3) The maximum allowable limit for interference power has been introduced to ensure that the TCAS control area is always sufficient to avoid collisions.

Hybrid monitoring is a feature that can be installed on TCAS II. Hybrid surveillance is a way of using aircraft TCAS modules to reduce S-mode requirements. In particular, TCAS devices with hybrid surveillance capabilities use passive surveillance rather than active surveillance to track competing aircraft that meet control criteria and cannot even predict long-range collision risks. When monitoring is used, TCAS transmits a request to the intruder's transceiver, and the transponder response provides the distance, direction, and altitude of the colliding aircraft. For passive tracking, the S mode transmitter sends location data to the integrated navigation resource.

If an intruder approaches and is threatened by a collision, active surveillance will follow by. Figure 1.6 pictures process of system transition from passive monitoring to active monitoring based on the risk of potential impacts. If the attacker stays away from the threat, he will be tracked through passive monitoring. TCAS actively monitors the passively monitored location every minute. If the colliding aircraft shows a direct threat in altitude or range, but not at the same time, passive surveillance will track it and use active TCAS queries to check passive surveillance locations every 10 seconds. If the attacker faces a direct threat in terms of height and length, he will be surveiled at a sampling rate of 1 Hz. The standard for the transition from passive monitoring to active monitoring aims to make all TCAS recommendations based on active monitoring.

The goal of hybrid monitoring is to lower the TCAS interrogation rate using ADS-B data received using enhanced Mode S messages without affecting the safety and effectiveness of TCAS.

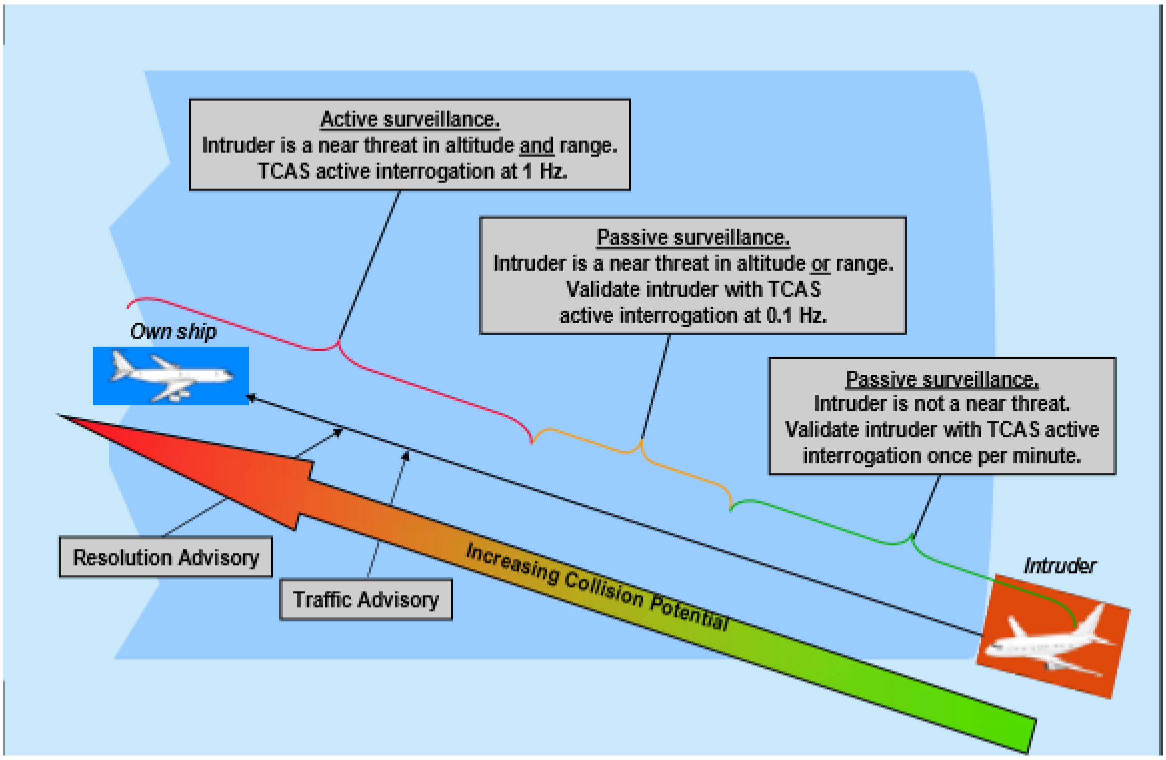


Figure 1.6. Transition from Passive to Active Surveillance

1.4 TCAS Electromagnetic Compatibility

TCAS has many design features to prevent TCAS from interfering with other wireless devices that use the 1030 / 1090MHz bandwidth. The Mode S signal used by TCAS also meets the requirements of Modes A and C of the secondary ground-based surveillance radar system and monitors the Mode S frequency to ensure that the distance measurement (DME) channel is continuous.

The TCAS interference limiting ability also helps supply electromagnetic compatibility with ATC radar systems. For comprehensive analysis, computer simulation and equipment testing of the monitoring software version 7.0 and above, no major failures occurred every time between TCAS, secondary additional tracking radar and supply the DME system. [5,21]

1.5 Limitations of TCAS II

The efficiency and performance of TCAS is subject to several system limitations, including performance and operational limitations. These limits are as follows:

Aircraft not equipped with a transponder or aircraft with non-operated transponder will not be recognized.

If there is no transmitter / receiver report height, the RA will not be issued to the traffic.

Aircraft with vertical speeds above 10,000 ft/min will not issue warnings (TA or RA).

The TCAS II system fails automatically if the signal from the aircraft's radio altimeter, barometric altimeter or transceiver disappears.

Some RA cannot be displayed at altitudes based on the input of the radio altimeter.

(a) 1,550 feet (+/- 100 feet) and below; increase descend RAs is prohibited;

(b) 1100 feet (+/- 100 feet) and lower downstream RAs are prohibited;

(c) 1000 feet (+/- 100 feet) and below are all RAs prohibited;

(d) 500 feet (+/- 100 feet) and under all aural unnuations (warnings) are prohibited

Climbing and increase Climbing RA may be banned if the several altitudes is exceeded or if the aircraft uses certain configurations. These restrictions are installed during using program contacts.

Due to interference reduction algorithms, TCAS II may not be able to show all close-distance planes with installed transceivers in densely populated areas.

Bearings antennas designated for TCAS II are not accurate for supporting horizontal operation based only on the width of motion. Therefore, it is impossible to perform a horizontal operation that only depends on the information displayed on the traffic screen.

The Ground Proximity Warning System (GPWS), Terrain Avoidance Warning System (TAWS) and Wind Shear Warning are prioritized over the TCAS II. When GPWS/TAWS warning is activated, TCAS II prompt is not heard, only TA works with TCAS II. [6]

Conclution to chapter

This chapter showed principle of TCAS operation and considerd different versions of TCAS. Different ACAS standards were shown. Nowdays TCAS system version, which used is version 7.1 of TCAS II, and it must be equipped on all planes in European air space beginning from the 2015. After 2002 incident in Germany involving Tu-154 and Boeing-757 Version 7.1 started to develop. That incident showed problem, when pilots of Tu-154 didn’t follow instruction of TCAS system and collided with Boeing, that human mistake still can occure and one crew will not follow command or will perform reversive command. Reverse RA because of this problem was added in Version 7.1. TCAS system uses two types of commands to warn pilots about treat and prevent collision. They called traffic Advisory

(TA) and Resolution Advisory (RA). TA is issued when pilots must be warned about intruder plane. After issuance of RA command, pilots must follow it for avoiding collision. Also RA commands prioritized over ATC commands.

TCAS IV was proposed version of the system and its main apgrade was Horizontal Advisory mode, but because TCAS antennas has low accuracy in horizontal tracking and ADS-B system was developed, TCAS IV system was cancelled. Nowdays proposed standard is called ACAS X, which will feature different versions for commercial aircraft, unmanned vehicles and private aviation. ACAS Xa is designed for commercial aviation and hardware used the same as in TCAS II systems, so the transition to ACAS X could be faster and cheaper for airlines. TCAS II incorporates TCAS CPU, transponders in mode S and C an TA and RA displays, TCAS control panel and two antennas. TCAS uses transponders installed on aircraft to exchange data about their corresponding positions. ADS-B system integrated into a TCAS operation and tracks aircraft relative position in space to reduce rate of TCAS transponders interrogations and this working mode is called as "hybrid surveillance". ADS-B only detects and identifyes aircraft and used for reducing of usage of radio channel resources. ADS-B range for surveillance is bigger than TCAS normally uses, and it can detect conflicting aircraft earlier. ADS-B protocol integrated in TCAS system uses increased number of information transmitted, and this information can disturb for collision avoidance functioning.

CHAPTER 2
TCAS LOGIC OF OPERATION AND COLLISION AVOIDANCE CONCEPTS

Aoidance of air traffic collisions is considered to be complex issue. It took years to enhance TCAS compliance, global air traffic control systems, and existing cockpit procedures to develop acceptable solutions for system operation and upgrades. Collision avoidance operations is founded on CAS logic which known as collision avoidance system. To understand the working principle of CAS logic, the basic concepts of CAS logic must be considered. There are following terms; sensitivity level, tau, and protection size. [5,21]

2.1. Collision avoidance concepts

2.1.1. Sensetivity level

For CAS logic to work efficiently, there is a compromise between the protection you need and the warnings you don't need. This balance is done by using Sensitivity Level Control (SL), which helps controls the TA and RA output limits thresholds or tau thresholds. This controls the size of the airspace that can be protected around each aircraft which has TCAS system on board. The higher the SL level, the higher the airspace protection and the higher the alarm threshold. However, as the area of protected airspace increases, the number of unwanted warnings can increase. [5,21]

TCAS uses two main methods, which can determine the SL operating window.

1. It can be selected by pilot. The TCAS Control Panel allows pilots to chose three operating modes:

When the standby mode is selected, TCAS uses SL1 mode operation. Requests can’t be linked by TCAS in SL1 mode. SL1 is usually only identified and works properly when the aircraft is on the ground or a TCAS fault occurs. In most cases SL1 mode only can be selected by the pilot usin control panel.

Only TA mode can be chosen using control panel, which leads to TCAS operation in SL2 mode. Using SL2 mode, TCAS will perform all scanning functions and shows on screens TA as needed. RA won’t show in SL2.

If TA-RA or corresponding system operations are selected in the control panel, TCAS Logic selects the SL automatically according to the altitude of the aircraft. Table 2.1 pictures us that TCAS automatically changes the altitude level of SLs within this altitude range and the SLs which can be used at this altitude. Using SL modes, TCAS can carry out protective functions and issue RAs and TAs as needed.

2. Selecting on ground. Ground control don’t have agreement between pilots, FAA and ATC, and is not operating in US airspace, but its functioning is included in the TCAS function. This feature can allow you to use advanced messages to uninstall the running SL in C mode. According to the design of the TCAS system, Table 2.1 shows avaible SLs to use, but you can’t use SL1.

Selecting the TA-RA mode using control panel by pilots, the SL can be operated and automatically selected by the pressure altimeter input or aircraft's radar. According to data in the radar altimeter entry, the SL2 can be selected when the TCAS-equipend aircraft is less than 1,000 feet from ground level (AGL) (±100 feet). SA can’t be used in SL2 and only possible scenario of TA is issued.

From SL3 to SL7, issuance of RAs occurs when using using timings siastances shown in Table 2.1. SL3 data based on the altimeters o aircraft and other SLs are based on the aircraft barometric information from altimeter input data pressure altitude. [5,21]

Table 2.1. Sensitivity Level Definition and Alarm Thresholds

Own Altitude (feet)	SL	Tau (Seconds)		DMOD (nmi)		ZTHR (feet) Altitude Threshold		ALIM (feet)
		TA	RA	TA	RA	TA	RA	RA
< 1000 (AGL)	2	20	N/A	0.30	N/A	850	N/A	N/A
1000 - 2350 (AGL)	3	25	15	0.33	0.20	850	600	300
2350 – 5000	4	30	20	0.48	0.35	850	600	300
5000 – 10000	5	40	25	0.75	0.55	850	600	350
10000 – 20000	6	45	30	1.00	0.80	850	600	400
20000 – 42000	7	48	35	1.30	1.10	850	700	600
> 42000	7	48	35	1.30	1.10	1200	800	700

2.1.2. Tau

TCAS uses CPA time in most cases rather than distance to determine when to issue TA or RA. Tau is the probable number of seconds for the CPA or distancing the airplane flying at the same altitude. The distance tau is equal to the angle of inclination (nmi) divided by the approach speed (knots) multiplied by 3600. Vertical tau is same as the vertical approach speed at which two planes flying (ft/min) divided by the height of aircraft distance (in feet). 60.

Usage of TCAS II functions is based on the conceptual tau for all alarm functions. TA or RA can be displayed in case of certain threshold below of the tau range and vertical tau, depending on the sensitivity level.

The limitations shown in Figure 2.1 explains the dependance of distancing and closing speed in range, which can deploy TA at 40 second intervals and RA are deployed at 25 second tau distancing. This taus range for usage in SL5 mode. Similar graphs for other sensitivity levels are also can be created.

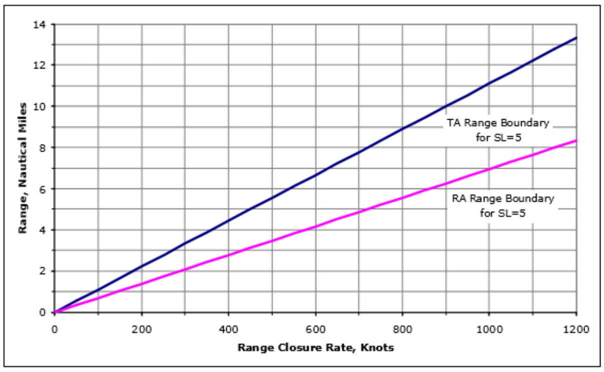


Figure 2.1. TA/RA Range boarders for SL5 using Unmodified Tau

The problem with the Tau in case of TA or RA not occuring in case the arrival velocity is too slow, the intruder plane can get very close to the area without going beyond the Tau area, as shown in Fig. 2.2. Figure 2.3 shows a definition of a boundary. In bigger distanced areas and high speeds, these limitations usually correspond to those defined by the main functions Tau. However, if the distance is small and the closing speeds are slow, then the limit of the variable Tau will be close to zero. This is called DMOD. TCAS, TA, and RA are allowed to be displayed by the corresponding changes at fixed thresholds in the DMOD range, or in these occurances where they were previously turned off. The value of this modifications depends on the sensitivity of operation level. Table 2.1 shows the values used for the version of TAs and RAs. [5,21]

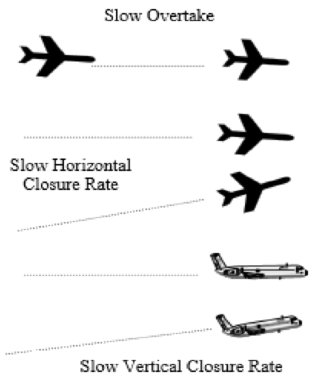


Figure 2.2. Modified Tau operations

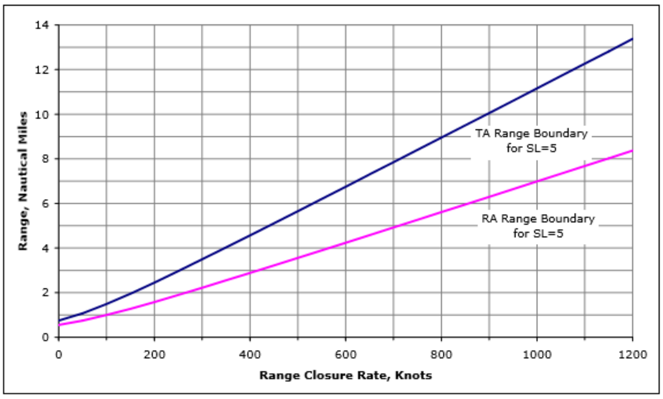


Figure 2.3. Modified TA/RA Range Tau Boundaries for SL5

If the vertical closing speed of the TCAS and the intruder is slow, or in case they are close to each other but difference in height, there are existance of similar problems. Fixed height threshold is used by TCAS called ZTHR to determine whether to use a vertical tau to issue TA or RA or not. Like DMOD, case of ZTHR depends on the values of sensitivity level, TA and RA thresholds are shown in Table 2.1. Figure 2.4 shows the integratin of altitude and separation by distance and vertical closing speed, using the SL5. This will result in usage of TA 40 seconds for the vertical difference tau and 25 seconds for the vertical speed tau RA. Value of ZTHR is displayed by the curve level of the low vertical turn-off rate. [5,21]

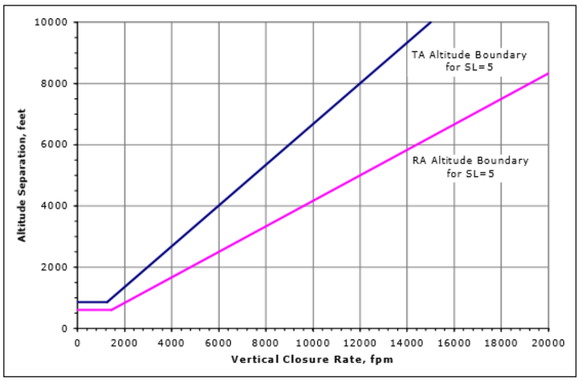


Figure 2.4. TA/RA Vertical Tau Boundaries for SL5

2.1.3. Protected volume

Protected volume circuled around all aircraft with the TCAS system on-board. Figure 2.5 shows that above horizontal volumes are formed by for DMOD and tau. The vertical dimensions of the volume determined to be protected by this thresholds.

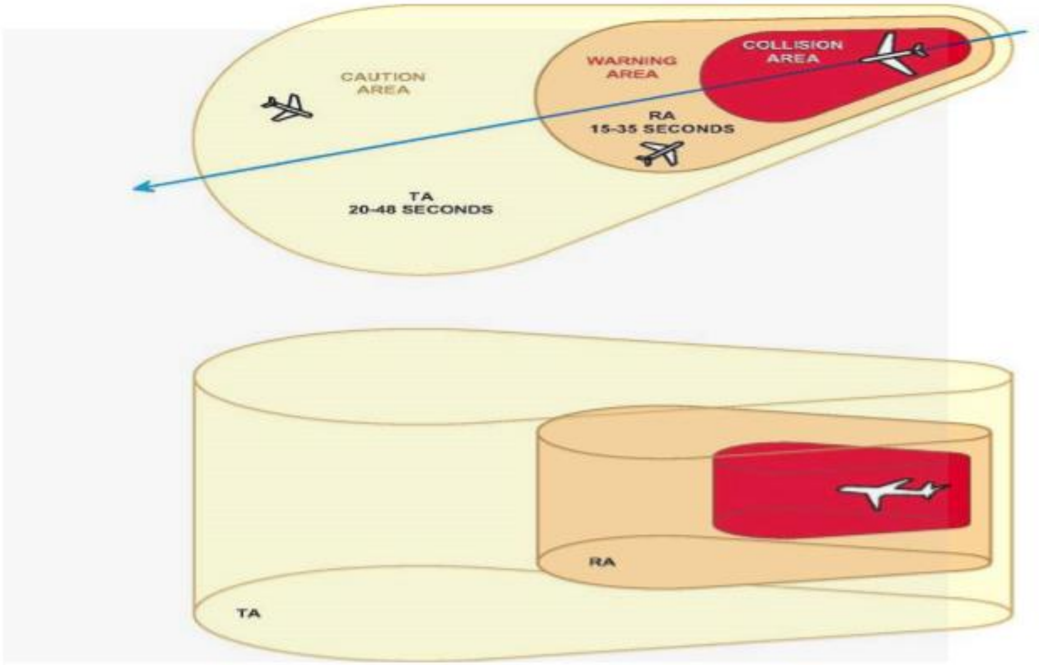


Figure 2.5. TCAS Protection Volume

The horizontal areas of the secured airspace can’t be dependend based on the distance, in only depends on datas which were calculated by value of tau and the secured horizontal distance. Area, on which the protected area is spred relies on data from the direction and speed of the conflicting aircrafts. The horizontal distance filter used to determine the size in order to use the distance and carrier information to remove RA from planes with sufficient lateral deflection.

The TCAS II can help avoid collisions when two aircraft are reducing distance from each other down horizontally at speeds up to 1200 knots and vertically at speeds up to 10,000 feet / minute (fpm). [5,21]

2.2. TCAS logic functions

Figure 2.6 shows the logic features that TCAS implefies to carry out collision avoidance functions. The description of these functions is intended to provide a general understanding of these functions. The design properties of an efficient collision avoidance system demand many special conditions that are functionally distributed and depend on the collision geometry, distance and altitude thresholds, and aircraft characteristics.

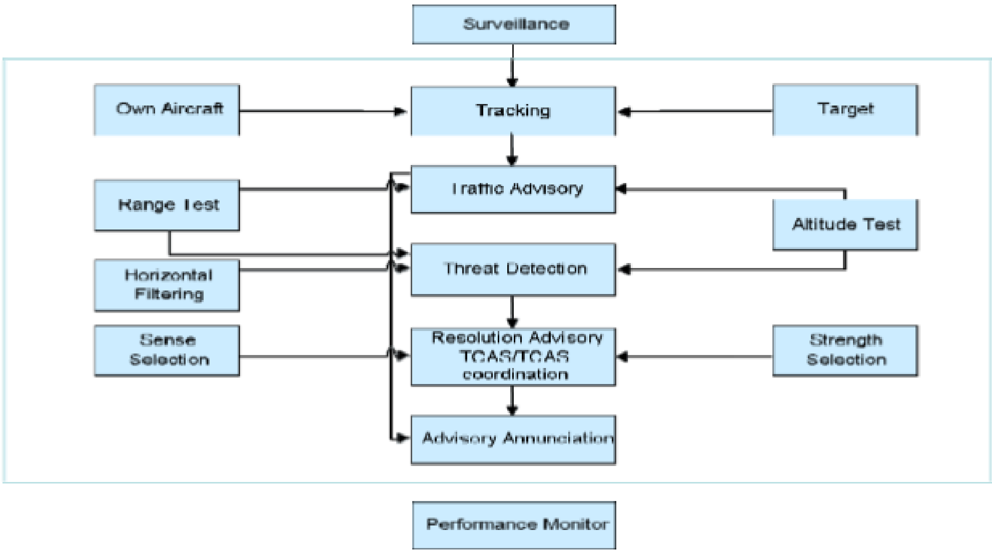


Figure 2.6. CAS Logic Functions

Utilizing the data about closest aircraft range and in case of availability altitude and direction provided by the CAS Monitor function, CAS Logic starts and continues to follow each aircraft's orbit. The continuous interval report calculates data used for the interval speed. Altitude data is determined to estimate the vertical velocity of each reported aircraft in close altitude. Evaluations for altitude tracking uses measures in 25-foot or 100-foot increments. The CAS tracking function tracking aircraft at designed features which takes into account vertical speeds of up to 10,000 feet per minute. Tracking information is used by CAS logic to determine time, at which CPA will come and the altitudes of each level within the CPA.

The difference between barometric altitude and radar altitudeused by CAS tracker to estimate the approximate altitude of the average altitude above sea level. This ground reasoning is useful when the plane is 1,750 feet above sea level. The ground pressure prediction is then derivated from the data of pressure altitudes obtained by all planes equipped with Method C to calculate the predicted ground level for each aircraft. With the difference less than 360 feet, TCAS decides that the connecting aircraft are located on the ground. If TCAS receives data, that intruding aircraft located on the ground, it is prohibited to show data about this aircraft. This method is graphed in Figure 2.7.

CAS Logic uses vertical speed data for the altitude and relative altitude of each aircraft. CAS Logic uses a unique aircraft altitude source that provides the highest accuracy. CAS tracking algorithm output data, namely distance, distance speed, relative altitude, and vertical speed, is passed to the traffic advice and threat detection logic to chose data whether

TA or RA is needed. Proprietary aircraft data can be presented as a low altitude report measured in increments of less than 10 feet or as an estimated altitude report in increments of up to 100 feet. [5,21]

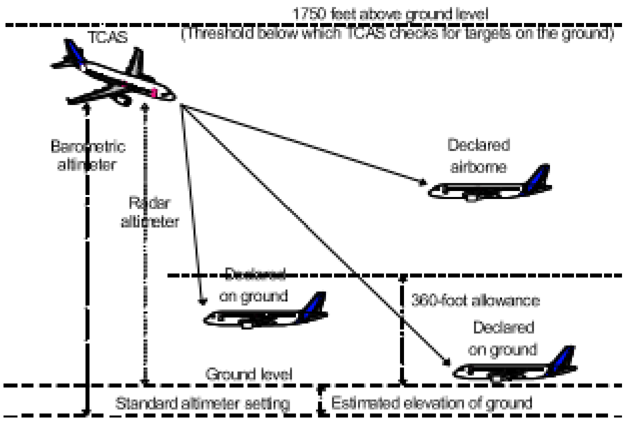


Figure 2.7. Mode C Target on Ground Determination

An S-mode tranciever equiped aircraft is determined grounded if the conditions transmitted by the antenna in the aircraft's response or transceiver indicate that the aircraft located on the ground.

Perform range and altitude tests on each altitude report target using the routes of nearby aircraft. Table 2.1 shows test ranges, which are based thresholds for tau are. If the logic of operation decides that the other aircraft intruding in an airspace, that aircraft will trigger a TA.

If the aircraft does not report its altitude and shows that the tau calculated by the distance check is only within the tau RA threshold associated with the currently used SL, the aircraft is declared an intruder. Version 7.0 includes changes to ensure that TA status is maintained at a slower exit rate, which makes TA removal requirements more stringent. These changes are related to issues reported when multiple TAs are issued for the same plane target in the longitudinal approach and RVSM airspace.

Performing distance and height checks on each reported height aircraft. When RA observation and the total altitude or relative altitude related to the current SL appears, the the notification about trear will apear. Depending on the format of the meeting and the quality and elapsed time of the vertical routing data, the RA can be desided to be shown after or will not be selected. Intruders outside of high altitude cannot produce RA. Version 7.0 has made changes to the threat detection logic to improve the performance the logic in this direction of treat detection. [5,21]

2.3. Resolution Advisory Selection

If a conflicting plane is considered a threat, a two-step process is used to select the appropriate RA for the collision geometry. At first step appropriate RA is selected, including the choice of direction (up or down). Based on the intruder's distance and altitude path, logic models the intruder's current location. Then RA simulated by the CAS logic of the aircraft direction and chosed up or down as depicted using Figure 2.8. Determine which of these values provides the maximum vertical spacing is the main goal of operation.

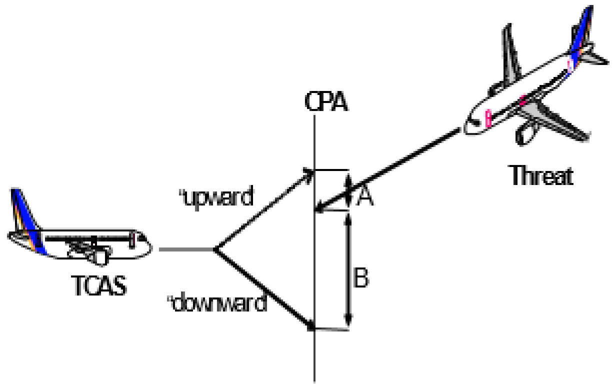


Figure 2.8. RA Sense Selection

Conflict pictured at Fig. 2.8, shows how the downlink logic is defined. This is due to the large vertical interval. If the TCAS visualization exceeds the height of the intruder, TCAS is designed to determine the time value in the absence of height traversal if the transit time value provides the vertical separation (ALIM) required by the CPA. At least if there is no absolute measurement of cross-elevation that provides an ALIM lens, the CPA will be determined even if the distance is increased by specifying the cross-height. If ALIM cannot obtain an intersection without altitude, the height RA is used. Figure 2.9. shows an example collision that simulates the RA value of the intersection of spikes and intersections without heights and chooses the feel of the RA without intersections. [5,21]

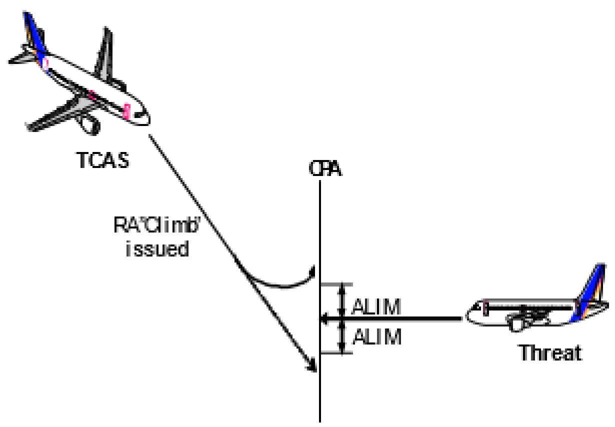


Figure 2.9. Selection of Non-Crossing RA Sense

Because certain flap and landing gear configurations limit the altitude performance of the aircraft, you can adjust the aircraft's installation to limit RA or increase lift values under certain factors. These limitations can be provided in real time via TCAS connections, program pins, or flight management system (FMS) inputs. If these RAs are disabled, following feature the RA selection criteria do not tryes considering them when selecting RAs. If the downward RA cannot provide sufficient vertical isolation, an alternative RA is selected upward. TCAS has design feature, that allows to suppress RA when the height is below 1450 feet above sea level. RAs are less than 1100 feet above sea level, and all RAs are less than 1000 ± 100 feet above sea level. If the aircraft descends RA during landing at an altitude of 1100 feet, RA will be changed to RA instead of ascending.

At the second step a force of the advisory is choosing for RA. RA force is the speed of the vertical trajectory required conflict resolution.

RA can be similar to the "negative" equivalent of positive or negative (for example, "vertical speed limit" (VSL)). Classification of RA can be preventive or corrective, depending on the presence or absence of coordination between the aircraft and the target. The modified RA requires a vertical speed change, while the preventive RA does not require a vertical speed change. [5,21]

Version 7.0 introduces a new component that lowers the initial frequency of the RA, which changes the current vertical speed of the aircraft. If two aircraft equipped with TCAS converge vertically at opposite velocities and are now sufficiently far apart, TCAS will first charge the vertical speed limit RA (VSL or negative) and the pilot will be nearby. Increases the potential intent to align with the aircraft in flight. If for initial RA no responce is detected, or if one plane is accelerating (vertical) towards another plane, the initial RA is will be stronger as needed. This change was further implemented to reduce the frequency found of initial RAs that change following the vertical speed of an aircraft, as filling pilots did not follow most commands RAs and the following were considered became catastrophic by air traffic controllers (for example). Climb the aircraft where RA descends. [5,21]

Version 7.1 introduced an exception following to the most destructive RA rules. After TCAS version 7.0 was introduced into the airspace, an initial response making following of the modified RA-VSL limiting (pronounced "vertical velocity adjustment, adjustment") was detected. The correct answer for AVSA RA because is to always reduce the vertical adjusted speed. Several collisions were looking observed as the pilot increased vertical speed and limiting the distance between owning the plane and the intruder. In version 7.1, all modified RA-VSLs that require non-zero flying vertical velocities (500, 1,000, or 2,000 ft / min) are converted from RA-VSL to 0 ft / min and "level off" to pilots. Is displayed as. The VSL 0 fpm RA is more powerful than necessary, but this change reflects the intent of the VSL's adjustments, that is, to clarify the transition to level flight. It was done. [5,21]

Table 2.2. Possible Initial RAs for Single Threat

RA Type	Upward Sense		Downward Sense	
	RA	Required Vertical Rate (fpm)	RA	Required Vertical Rate (fpm)
Positive (Corrective)	Climb	1500 to 2000	Descend	-1500 to -2000
Positive (Corrective)	Crossing Climb	1500 to 2000	Crossing Descend	-1500 to -2000
Positive (Corrective)	Crossing Maintain Climb	1500 to 4400	Crossing Maintain Descend	-1500 to -4400
Positive (Corrective)	Maintain Climb	1500 to 4400	Maintain Descend	-1500 to -4400
Negative (Corrective)	Reduce Descent	0	Reduce Climb	0
*Negative (Corrective)	Reduce Descent	> -500	Reduce Climb	< 500
*Negative (Corrective)	Reduce Descent	> -1000	Reduce Climb	< 1000
*Negative (Corrective)	Reduce Descent	> -2000	Reduce Climb	< 2000
Negative (Preventive)	Do Not Descend	> 0	Do Not Climb	< 0
Negative (Preventive)	Do Not Descend > 500 fpm	> -500	Do Not Climb > 500 fpm	< 500
Negative (Preventive)	Do Not Descend > 1000 fpm	> -1000	Do Not Climb > 1000 fpm	< 1000
Negative (Preventive)	Do Not Descend > 2000 fpm	> -2000	Do Not Climb > 2000 fpm	< 2000

Table 2.2 lists the possible advisories looking that can be given as the initial RA driving if only one intruder is involved choosing in the collision avoidance encounter. After selecting becaming the source RA, the CAS logic trying continuously monitors the vertical separation could provided by the CPA and, folllowing if necessary, changes the source RA.

In some cases, intruders perform vertical operations to reduce the efficiency of outbound RAs. In such cases, the initializiong of RA is modified to increase powerfull or meaning of the original RA initially. RAs in the opposite (opposite) sense flying are discussed separately. VSL is modified by making it a more corresponding VSL that actively increases or decreases RA. Ascending or descending RA ascends to RA ascending / descending. RA can only be released for ascending / descending if it has a different meaning than ascending, negative RA, or RA following gain.

Figure 2.10 shows us a transition where it is necessary to judje increase the descent rating from the 1500 fpm making required by the initial RA to 2500 fpm.

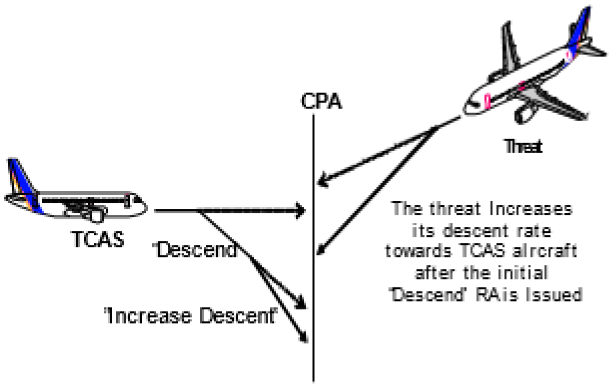


Figure 2.10. Example of an Increase Descent RA.

The changes will be made in agreement agreed with version 7.0 and above. The logic for changing this value is very similar to the logic operations previously available to non-TCAS in emergencies. Figure 2.11 shows the initial encounter when the RA needs to descend after the striker is operated, with the first RA climb required for the climb.

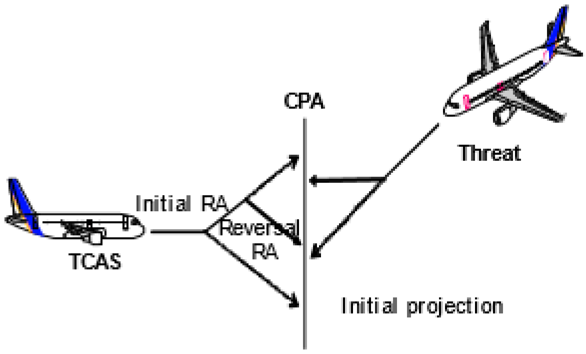


Figure 2.11. RA Reversal

After the Airspace 7.0 version was introduced, a loophole was discovered in the logic of modifying the reflection value. This problem was first observed in a collision with two helicopters equipped with TCAS. In this case, the aircraft took off and landed in the same vertical direction, one pilot followed the TCAS RA, and the looking other pilot ignored the RA. This collision geometry has proven to be a problem in collisions with TCAS instead of TCAS aircraft. Version 7.1 added new reflection generation logic to solve this situation. If the aircraft performs a coordinated collision or dangerous maneuver regardless of the RA, or if unlimited hazards move around the aircraft and interfere with the RA in the vertical direction, a new logic will emerge. Identify vertical tracking geometry with short error distance.

TCAS is designed to supress conflicts with multiple conflicting airplanes, i.e. conflicts in which multiple threats are finded at the same time. TCAS seeks to remove these types of obstacles by selecting one or a group of RAs that can be appropriately isolated from each intruder. RAs selected for this type of conflict may not be able to isolate ALIM from all problems. The initial reaction to many threats should be one of the sources shown in Table 2.2, or a mix of up and down passive MFIs such as “non-bullish” and “non-falling” velocities to better address the problem that arises can.

If the CAS logic during the RA determines that the response to the positive RA followed a vertical ALIM break to the CPA (that is, the aircraft was safely split at altitude but not within reach), the parent RA determines that the RA Weak against (increased first RA) or increased RA (after decreased first RA). This is done to reduce the deviation of TCAS from the original altitude of the aircraft.

Starting with 7.0, after reaching an ALIM gap called a patch, the resulting RA is called "not going down" or "not going up". With version 7.0, RA is displayed as "Vertical Velocity Adjustment, Adjustment". Version 7.1 displays RA as "level off, level off". (Version 6.04a retains the original protection designation, which means that RA is known as "vertical monitor speed"). Starting with 7.0, negative RAs are not obfuscated and the original RAs are retained until the CPA unless the AR is enhanced or modified.

Cancel all high-speed flights after the CPA has passed and the distance between the TCAS aircraft and the emergency aircraft has increased, or if the horizontal obstacle distance filter can determine that the horizontal obstacle distance is sufficient before the CPA is needed. [5,21]

2.4. TCAS/TCAS and Air/Ground Coordinations

During the TCAS/TCAS initial interaction, each aircraft sends going request to the other aircraft via the Mode S link, allowing the two aircraft to select helping RAs. During the RA, the RA sends a coordination request once every second, and uses the same 1030/1090 MHz channel to respond to the monitoring request. The coordinated investigation provided knowladge information about the collision avoidance interaction between following the aircraft's intention to process and another planes TCAS-equipped intruder using the RA. Coordinated investigation information is included in the appendix. For example, if an aircraft chooses an upstream RA, the consent request will be forwarded to another aircraft, and the RA selection will be limited to that aircraft. The bottom of the RA is determined by the hazard plane based on collision geometry and RA selection logic.

The basic rule for selecting TCAS / TCAS collisions avoid is that each TCAS must ensure that it has received an intent message from another aircraft before having selecting the RA direction. When TCAS receives an intentional message, it chooses helping the opposite direction to the value keeping selected by the other aircraft and sends it via an adjustment request. (Except for version 7.0 and later, if the intruder chooses the meaning of height and the intruder meets a set of conditions that can cover that meaning.) If TCAS has not received previous notice, the meaning is the same choosen depending on the impact shape. It's as if the intruder's aircraft had no TCAS.

In most TCAS/TCAS collisions, two aircraft decided declaring the other a threat at slightly different times. In cases like these, the adjustment is made in line with the first aircraft, the second threat declared, choosing to recognize the RA based on the shape of the impact and notifying the other aircraft of its intent. Following other plane announced that for the vatching other plane was in danger. If you have already received Level 1 Intent, please select another RA idea. While examining the agreed investigation, the selected ideas with complementary meaning will be transferred to the other plane.

Sometimes, two planes will advertise each other as a threat at the same time, so the two planes will choose their RA sense based on the geometry of the collision. In these cases, both planes helping may choose the corresponding RA direction. In case of this happenning, the plane with address S in the higher mode will detect that it has been selected and changed the same value.

If the collision geometry changes after the initial TCAS gives RA, version 7.0 adds the ability to reverse RA in a coordinated response. The changes made by the RA in the coordination meeting will be communicated to the pilots, just like the RA's invitation to participants from outside the TCAS. If a low-end aircraft is installed with S re mode of version 7.0 and above and a coordinated collision occurs, the meaning of the initial RA can be changed, and the aircraft with the evolution of the S re mode can be reported. The aircraft will reverse the RA value displayed in the correponding S mode, and the aircraft with a high taking order in the S direction can be equipped with any equiped type of TCAS. In the case of coordination conflict, only one RA call can be transmitted based on the returning change of getting conflict geometry.

Using S-mode connected data, TCAS can send RA reports to S-mode sensors. The S-type transponder allows provides this information in reply to the request of the S-type ground sensor to receive TCAS signaling information.

Starting from version 7.0 and higher, RA data is transmitted in automatic mode in the TCAS 1030MHz frequency band. The message sent by this RA is a "highly coordinated" message, but it is suitable for 1030 MHz ground receivers. This transmission is sent every occurance the RA is firstly displayed to the crew, and the RA is refreshed every number 8 of following times.

Starting from version 7.0, in range of 18 seconds from the end of RA, report of RA and RA message broadcasted contain RA termination (RAT) bit, indicating information that RA is not displayed in the beta signal. [5,21]

2.5. Aural Annunciations and performance monitoring

When the collision avoidance algorithm saying that displays TA or RA recommendations, a voice language warning will be issued for informating the pilot of the traffic knowing and the information displayed on the RA display. These audio signals can be heard on the pilot's headset through special speakers installed in the cockpit or aircraft audio panel. Table 2.3 shows a list of voice annonciations that corresponds to the recommendations used in all following three versions of TCAS. The affected TCAS notices are marked with version 7.1. Audio alarms are suppressed by systems at 500 ± 100 feet operatingbelow sea level.

The TCAS audio alarm is integrated with the audio alarms of other aircraft systems on board. Priority schemes created espetially for these acoustic warnings, wind shear detection and ground proximity warning system (GPWS) systems provide and has working principle higher priority warnings than TCAS warnings. When GPWS is enabled, TCAS input alarm or audio alarm is disabled. [5,21]

Table 2.3. TCAS Aural Annunciations

TCAS Advisory	Version 7.1 Annunciation	Version 7.0 Annunciation	6.04a Annunciation
Traffic Advisory	Traffic, Traffic		
Climb RA	Climb, Climb		Climb, Climb, Climb
Descend RA	Descend, Descend		Descend, Descend, Descend
Altitude Crossing Climb RA	Climb, Crossing Climb; Climb, Crossing Climb		
Altitude Crossing Descend RA	Descend, Crossing Descend; Descend, Crossing Descend		
Reduce Climb RA	Level Off, Level Off	Adjust Vertical Speed, Adjust	Reduce Climb, Reduce Climb
Reduce Descent RA	Level Off, Level Off	Adjust Vertical Speed, Adjust	Reduce Descent, Reduce Descent
RA Reversal to Climb RA	Climb, Climb NOW; Climb, Climb NOW		
RA Reversal to Descend RA	Descend, Descend NOW; Descend, Descend NOW		
Increase Climb RA	Increase Climb, Increase Climb		
Increase Descent RA	Increase Descent, Increase Descent		
Maintain Rate RA	Maintain Vertical Speed, Maintain		Monitor Vertical Speed
Altitude Crossing, Maintain Rate RA (Climb and Descend)	Maintain Vertical Speed, Crossing Maintain		Monitor Vertical Speed
Weakening of RA	Level Off, Level Off	Adjust Vertical Speed, Adjust	Monitor Vertical Speed
Preventive RA (no change in vertical speed required)	Monitor Vertical Speed		Monitor Vertical Speed, Monitor Vertical Speed
RA Removed	Clear of Conflict		

TCAS has installed performance monitoring programming devices in its system, which can continuously all time and automatically watching check the performance and status of TCAS. TCAS activity monitoring works after its activation. It also includes Beta testing features, including performance monitoring, on-screen TCAS advanced testing and audio alerts. The performance monitor operation supports and advanced maintenance diagnostics, which can be used for operating by maintenance personnel when the aircraft is parked on the ground.

The performance monitor shows and improves most of the input parameters transmitted from other aircraft systems and the operations of performance of TCAS processor. For example, you can enter the altitude data of your own aircraft and receiver connect TCAS to the aircraft monitors suppression bus.

In case of monitoring detecting unusual TCAS performance or mistaken inputs from the required onboard system, an error message will be sent to the pilot. If necessary, you can disable or switch off all including or some of the TCAS functions. If the TCAS function is disabled by the performance monitor, the complete error will be shown and when the detected error is corrected. [5,21]

Conclusion to chapter

This chapter considered TCAS logic and Collision Avoidance Concepts The basic CAS concepts are called as sensitivity level, tau, and protected volume. Understending of this concept is important in order for explanation of CAS logic.

Sensitivity level (SL) controls planes tau thresholds time for TA and RA flying issuance, changing dimensions volumes of the protected airspace around each flying aircraft, equipped with TCAS control system. Higher SL number increases protected airspace volume and alerting thresholds are longer occurring. With increased amount of protected volume of airspace, number of unnecessary traffic alerts increases. Tau is considered to be an approximation of time in seconds to closest point of approach. TCAS tau range is equal to the slant range (nmi) divided by the closing speed (knots) multiplied by 3600. The vertical tau is considered to be equal to the altitude aircraft separation (feet) divided by number of the vertical closing speed of the two-conflicting aircraft (feet/minute) times divided 60. Based on vertical and range tau, utilizing when both are less then certain information about threshold value, a TA or RA command informations are displayed.

A protected volume is quantity of airspace volume, which surround aircraft with TCAS – equipped aircraft. It relies on data from SL and tau. The size in volume of the protected volume airspace depends on the speed and direction of the aircraft movement involved in conflicting encounters. TCAS logic functions are following: surveillance functions, traffic functions, threat detection functions, TA and RA issuance and TCAS/TCAS coordination.

Selection of Resolution Advisories includes initial RA selection, sense reversals, following by streghtening and weakening of advisories. Using initial RA selection main purpose used is to select RA sense orientations (upward or downward) based on the data about altitude and range of intruder plane in conflict to provide bigger vertical separation at CPA. It considerd also taken in accout that at some aircrafts landing gear and flaps configurations climb performance can become limited maneuverability, that’s why it can be configured by pilots for inhibiting Climb or Increase Climb RA commands. After initial choosing RA sense, the strength powerful of advisory must be selected. Initial Sense reversal is used in the case of both conflicting planes climbing or descending while one of the conflicting plane pilots following TCAS RA and the other pilot dont follows RA command. Sence reversal was introduced in TCAS II Version 7.1. Weakening advisory function is used when both aircraft can become safely separated in altitude but not in safe range, after this the initial RA command will be weakened because it will minimize the displacement from planned aircraft initial altitude.

In case of TCAS issuing TA or RA commabd, a voice commands are used for assisting and insuring that pilots knows about TCAS recommendations are displayed on aircrafts traffic and RA displays. These aural annunciations are provided using a spetial dedicated speaker or can be heard by pilots in their headsets. Voice commands can be different, depending on TCAS version.

CHAPTER 3
MARKETING MONITORING OF TCAS SYSTEM AND ITS EFFICIENCY OF OPERATION

TCAS II systems can be manufactured by the following companies: Garmin, Rockwell Collins, Honeywell and ACSS. Nowdays TCAS II Version 7.1 is mandatory for installation on-board of aircraft in most countries, that's why only Version 7.1 compatible systems will be described.

Nowdays ADS-B system is implemented for operation in TCAS hybrid survelliance, so these systems must be compatible with ADS-B operation.

Wider distribution and compatibility with a bigger number of aircraft is considered to be advantage of one system over others.

3.1. Honeywell solutions for TCAS systems

3.1.1 SmartTraffic CAS 100 System

The SmartTraffic Collision Avoidance System (CAS) 100 is available in three models: Commercial Traffic Warning and Collision Avoidance System (TCAS). This new generation of products, called the TCAS TPA-100 processor series, utilizes enough processing power for future implementation of ADS-B IN functions.

Three versions of Honeywell commercial TCAS are offered which uses the TPA-100 TCAS processor which are called the TPA-100A/B/C.

TPA-100A – considered as a successor of the TPA-81A system, and does not require for replacement of aircraft equipment.

TPA-100B – serves as a direct change for the TPA-81A, it is interchangeable with the equipment of a TPA-81A. supports Version 7.1 upgrade.

The traffic computer installed with Smart Traffic system has all the functions of TPA-100B, and provides the required ARINC 735B functions integrated into TCAS II functions and RTCA / DO-300 hybrid monitoring.

3.1.2. CAS-67A TCAS II System

Safely separate your aircraft from another aircraft equipped with an S, C, or A / C transponder. Transponders track the airspace around aircraft in which it equiped by interogating the receivers of another aircraft. The TCAS processor calculates the intruder's distance, height difference, directional velocity, and proximity, and compares the colliding plane data with the intruder's location to determine the collision probability.

You can provide intruder advice in the following modes: Solution Advice (RA), Non-threat, Proximity Advice (PA). Traffic Advice (TA).

Air-to-air adjustment occurs when both aircraft are using TCAS II system and a maneuver data link is present and established with the intruder’s aircraft through the Mode S transponder. The data link adjusts the resolution recommendations of the two aircraft and meets the compatible TCASII equipment. RTCA DO-160B/C/D environmental conditions

The CAS-67A model of TCAS II System elements consists of a Top & Bottom Antennas, Transponder & Control Unit, Processor, Display,

This system disadvantage is that CAS-67A lacks of ADS-B standart

3.2. ACSS TCAS-2000

The ACSS solution are called TCAS 2000 and TCASII. In Table 3.1 we can see differences in system features between TCAS2000 and TCASII. Today, ACSS manufactured TCAS solution are most widespread TCAS versions in the world. Nowdays in production of ACSS TCAS modules only TCAS2000 systems are made, while ACSS TCAS II only has legacy support. Version 7.1 was first certified in ACSS systems.

Table 3.1 Difference between TCAS 2000 and TCAS II

System features	*TCAS* 2000	*TCAS* II
Mode-S transponder viewing area	Up to 80 NMI	40 NMI
ATC transponder surveillance area	20 NMI	
Passive surveillance zone in *ADS-B* transponder	> 100 NMI	Absent
Number of aircraft, which tracked by system	50	
Horizontal speed of approach (max)	1200 Knots	
Vertical approach speed (max)	10000 Ft/min	
Capability to coordinate the maneuver of departure with other aircraft equipped with TCAS	Yes	
Providing recommendations for standard maneuvers according to the instructions for climbing or descent with the recommended vertical speed	Yes	
Giving recommendations of accelerated maneuver following instructions about increasing or decreasing vertical speed of changing altitude or instructions about changing direction of the maneuver to the opposite direction	Yes	

Fron the beginning of operation in 1997, more than 10,000 TCAS2000 computers have been delivered for more than 200 operators around the world. TCAS 2000 is available for use from most equipment manufacturers such as Airbus, Boeing, Bombardier and Antonov. Many airlines and aviation industry leaders chose TCAS2000 as their TCAS operating systems.

The TCAS 2000 gives pilots the highest accuracy ever acceptable (2° rms and TSO 9° specifications) and higher range of monitoring (80 nmi active, more then 100 nmi passive). ATCRBS advanced algorithm, ACSS height algorithm and direction tracking algorithm provide a probability greater than 99% and reduce the number of defective tracks by 0.5% (allowed by FAA Advisory No. 20-131A. 60% improvement over the made).

With 20 years of experience of ACSS in TCAS modules researches, and its pedigree can be traced back to the first Sperry Dalmo Victor TCAS II concept variant. The latest requirements of RTCA DO-185A are met by TCAS 2000 system (the minimum operating performance standard change for TCAS equipment 7), ARINC 735A (ACAS II ARINC standard) and ICAO SARPS (standards and recommended practices), and is fully compliant) and corresponds with ACASII obligations.

Only ACSS can give customers the antennas with best quality TCAS technology in the industry. Amplitude single pulse sensing gives bigger expluatation benefits such as insensitivity to cable length differences of up to 7 feet and immunity to non-frequency responses. The ACSS Amplitude Monopulse System can always accept 360-degree signal without scanning, allowing you to catch intruders quickly and maximize alert time.

TCAS 2000 significantly upgrades stability and reduces operating costs by lowering weight and power consumption compared to first-generation TCAS II systems. Other features include internal data logging using PC-based suite for analysis and built-in software update capabilities can help operators to be more operational.

TCAS 2000 corresponds for requirments given by DO-160C Environmental Certification, leading to an opportunity that it can be installed outside using high-pressure aircraft ability.

While being developed, TCAS 2000 gone testing of accelerated lifeltime (HALT), and before delivery it passes stress tests to met required standarts (HASS).

TCAS 2000 design is aimed for future possible requirements, such as Change 8, and has possibility of installation ADS-B hybrid surveillance package (ADS-B extended squitter receive capability is already functional). By adding the newest Thales Avionics Ground Collision Avoidance Module concept of TAWS system to the TCAS 2000 LRU, the TCAS 2000 computer can be easily upgraded.

Main parameters:

- Spetial amplitude one-pulsed directed antenna

- Better conflicting aircrafts monitoring performance
- Bigger range of finding other planes (up to 100nm)
- Significant bigger place for newer security functions
- More reliable because of use of better designs
- Standard helps for better visibility for traffic split-up
- Easy software future versions updates using ARINC 615 system data loader
- It has full compatibility with S mode transponders currently in use

3.3. TCAS system on Boeing 737NG

Following components are installed on Boeing 737 for TCAS II operation:

- TCAS two antennas directional
- One unit of TCAS computer
- In cockpit installed ATC/TCAS control panel.

TCAS system are interacting with following system components:

- Two ATC transponders
- PSEU
- Landing gear deploys system
- Common display system display electronic units
- Radio altimeters
- Remote electronics unit
- Ground proximity (GPWC) warning system

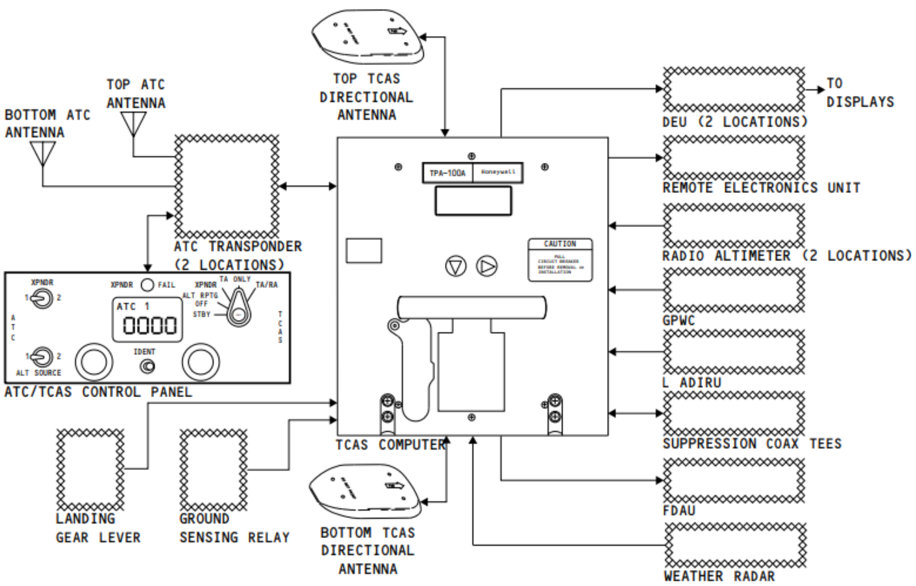


Figure 3.1 TCAS general description

TCAS computer placement on-board is the electronic equipment compartment location

The following components inerfaces with TCAS in the compartment:

• EFIS control panel

• outboard display unit

• EFIS control panel

• inboard display unit

• ATC/TCAS panel controlling.

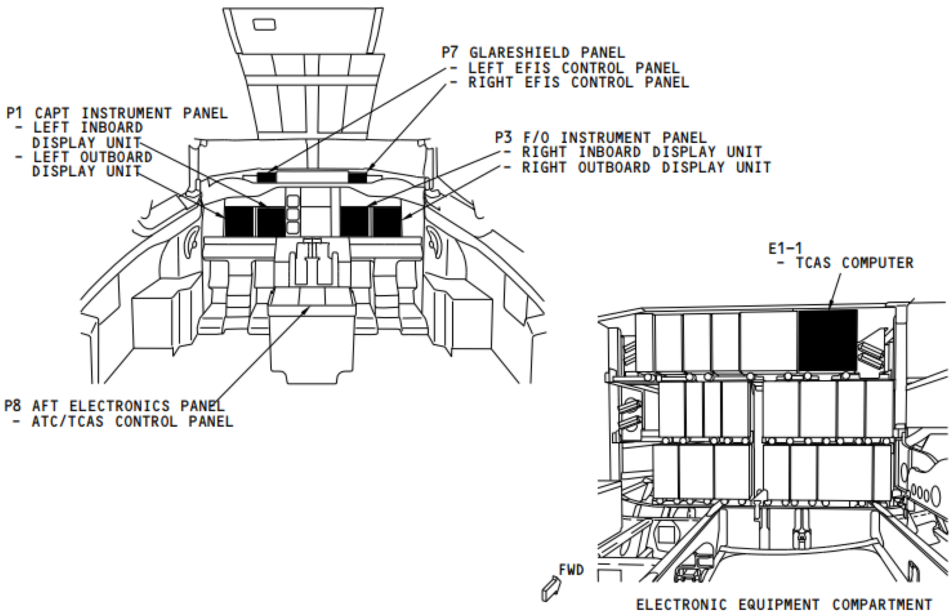


Figure 3.2 TCAS component location

TCAS the directional antenna on top of the aircraft stationed 385 on upper part of the plane fuselage. TCAS directional antenna located in bottom part stated 305 bottomming the fuselage.

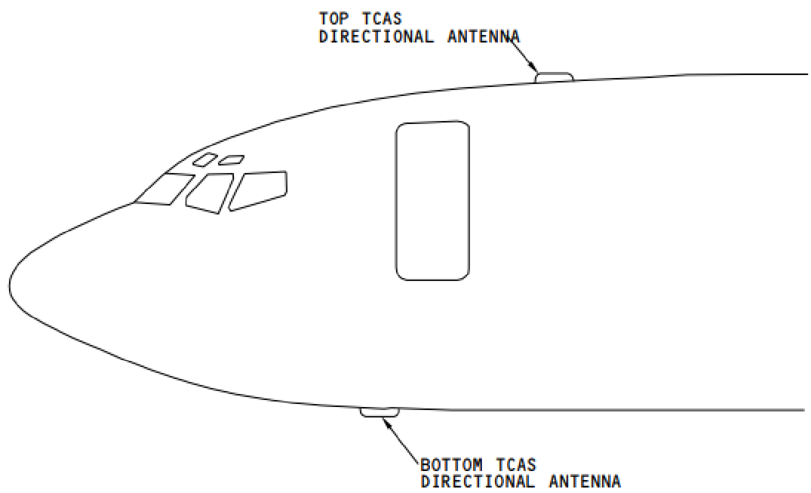


Figure 3.3. TCAS antenna location

TCAS analog and discrete interfaces interacts with following components:

• TCAS bottom and directional up antennas

• Landing lever gear switch

• Unit (PSEU) Proximity Electronic Switch

Power The TCAS computer gets 115v ac from AC transfer bus-1 through the TCAS circuit breaker on the P18 circuit breaker panel.

TCAS computer powered with using of aircrafts own electric system consisted with 115v AC and TCAS circuit breaker

Antennas

Two TCAS directional antennas are in use. These antennas consume the response signal from the aircraft. It also sends interrogation TCAS new signal.

Separately from the landing gear lever switch to notify the TCAS computer that there was deployment of landing gear. TCAS computer when obtaining something this discrete spetial value, the TCAS computer turns the directional antenna below it into an multi-direction signals from antenna.

Independent of PSEU, provide air or ground status for TCAS equipment. Ground / AIR signals forbids prohibits TCAS from running on the ground and prohibits testing in the air. The air/ground signalings also helps the change of the flight parts in the TCAS spetial partial memory storage.

Systems sends a spetial value to the TCAS computer. GPWC sometimes sends voice messages, this dispersion suppresses TCAS auditory and visual warnings.

Weather radar

TCAS systems from the weather radar can get a known signal. When the weather radar issues a predictive around warning, this conditionings suppresses all TCAS pronaunced warnings and modifies RA to TA.

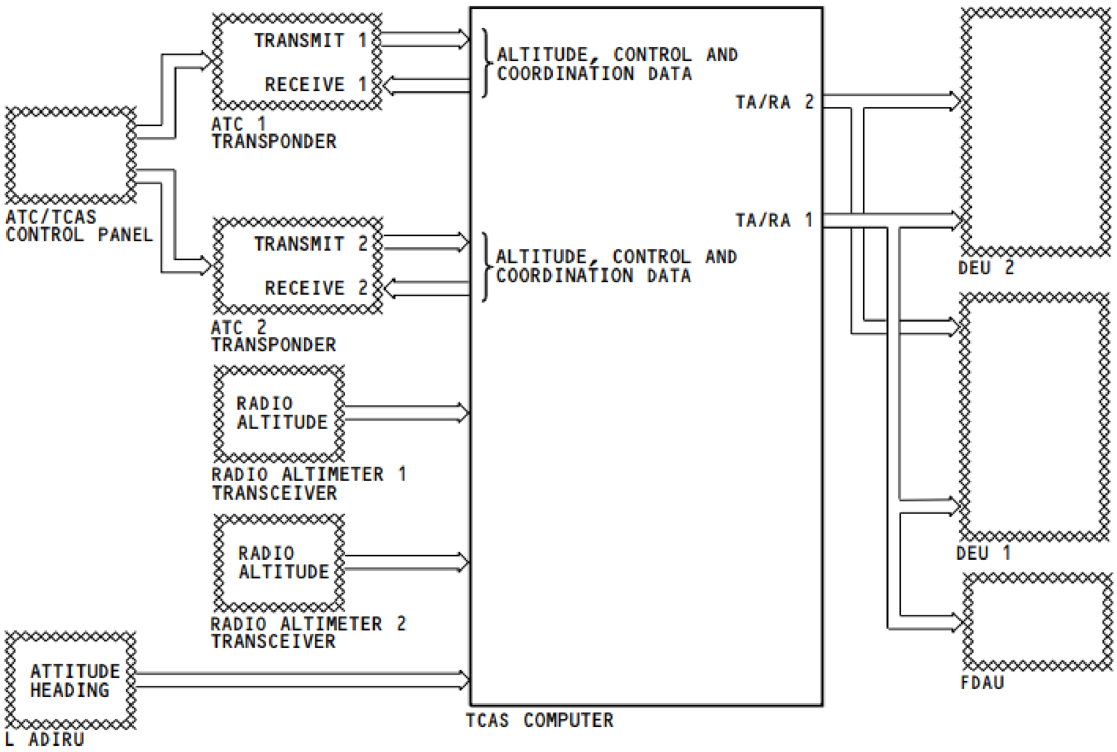


Figure 3.4 TCAS digital interfaces

The main component of this system is computer. It utilizes following tasks:

Monitoring, trailing, coordination of air maneuvers.

The TCAS computer sends signals which tell the flight crew to make one of these maneuvers:

TCAS systems computer sends instructionz for the crew to perform one of the following actions: Keeping the present flight path; Make movements in air to stop a predicted collision with other air traffic in the region.

Physical Description. TCAS system consists of 6 units. Weight of one unit is around 28 lbs (11.3 kg).

Performance Management Recording

A slot for Personal card is installed. The logging function provides the ability to store information about TCAS events and analyzing of flight events. The programming of the PCMCIA unit is made during the warehouse level or by spetial facility personnel to made troubleshooting for problematical faults.

• ACTIVE is showing that card performs recording

• FULL indicator showing when card completed recording

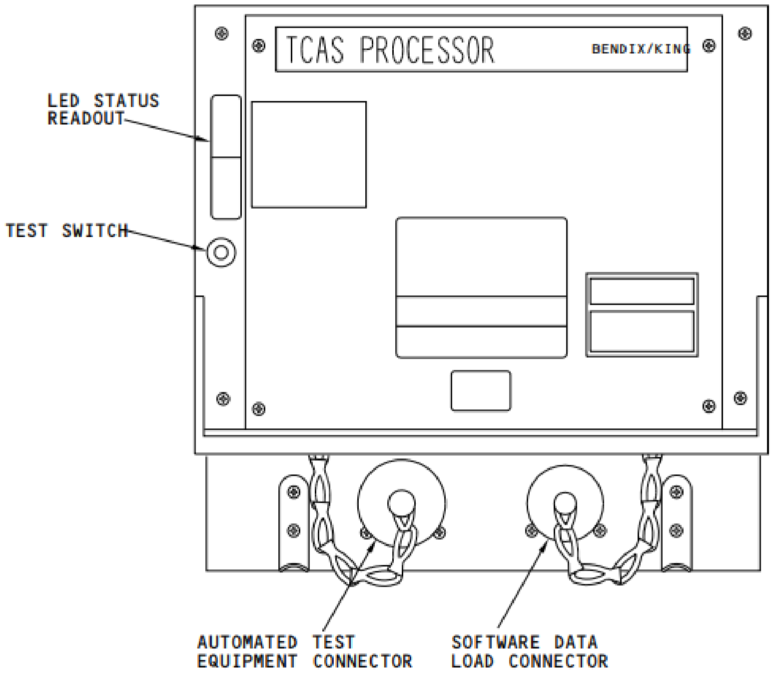


Figure 3.5 TCAS computer

General

The ATC/TCAS panels used for controling the TCAS computer in following modes

Above/Normal/Below Switch

Flight Level Pushbutton Switch

The flight level (FL) switch is a instant action switch. Pushing the switch makes display of the flight level altitude of the target be replaced with the relative altitude of the target. The flight level altitude shows on the ND for 15 seconds. The display then goes back to the relative altitude.

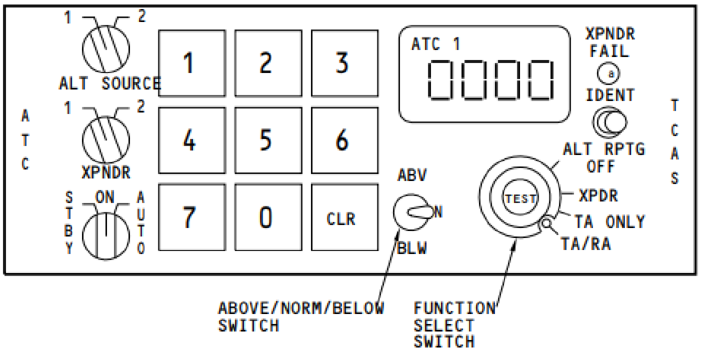


Figure 3.6 ATC/TCAS control panel

The TCAS uses a two directional antenna located at the bottom and ot top of the aircraft. The antennas are interchangeable because they are the same.

Physical Description

Four screws attach the antenna to the airplane. The radiation side of the antenna shows FWD and DO NOT PAINT

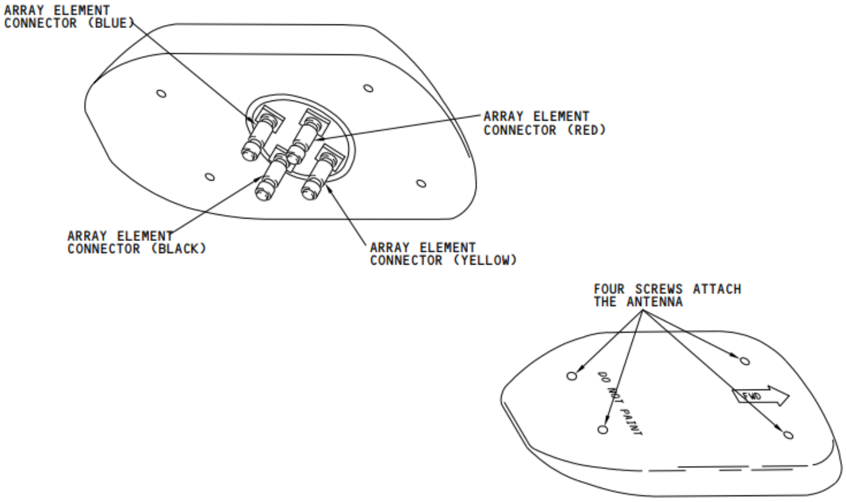


Figure 3.7 TCAS directional antenna

TCAS self testing feature on Boeing 737NG

Self-test can be started from the ATC/TCAS control panel or using the TCAS systems computer front panel test switch. While testing, TCAS sends signals to following components: NDs; ADIs

Indications of TCAS Self-Test –If case if test passes, the following ND data is shown:

• A cyan TCAS TEST message,

• A red TRAFFIC message,

• Amber symbols of traffic at the information 9:00 used position, -200 feet corresponding height with an up vertical movement icons and 3 km from the vehicle

White probable traffic symbol at the 1:00 position

In case of failed test TCAS TEST FAIL message replaces the TCAS TEST indication and don’t show traffic. TCAS and FAIL indicators can be displayed in amber and indication of TEST shows in cyan.

TCAS Indications of VSI test

If the test passes, probable the VSI shows the red prohibited banned vertical speed band from 0 to -6000 fpm. The VSI shows the red prohibited vertical speed band from +2000 to +6000 fpm. It also shows the green fly-to vertical speed band from 0 to +300 fpm. If the test fails, The VSI will not show the RA red or green bands. If the display is in the compacted mode, the ND does not show. The VSI shows the TCAS test messages when in the self-test. The TCAS message is in a box of the same color. These are the TCAS messages:

• TEST FAIL - cyan TEST and an amber FAIL display to show that TCAS did not pass the test

• TCAS TEST - cyan display to show that TCAS passed the test.

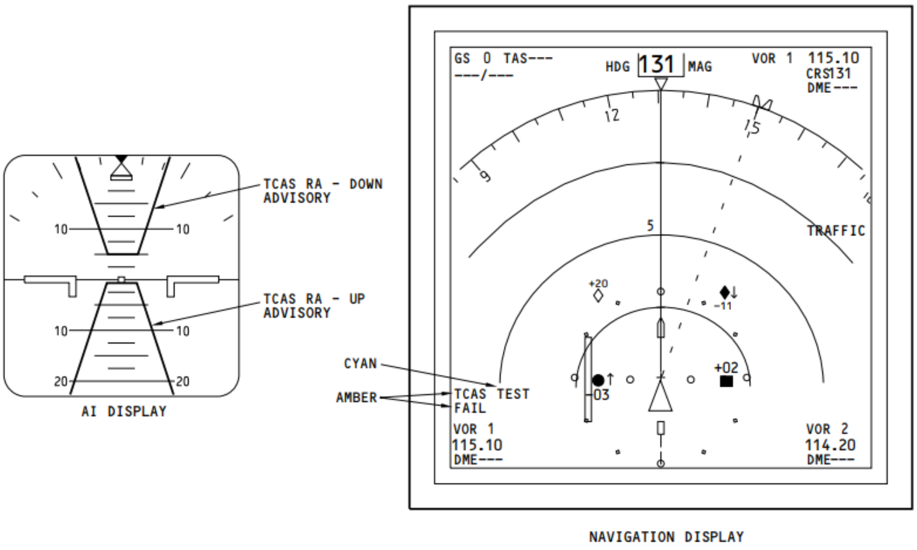


Figure 3.8 TCAS self-test indicators on display

Push while you hold the test switch remote on the front panel usage starting a self-test. The LED segments on the front panel turn on in this sequence:

• All LED display segments come on for three seconds

• All LED segments go off for three seconds

• Applicable LED code shows the status of TCAS.

If the test passes, OK will show on the LEDs. If there is a failure, the fault code shows. The fault codes show in order for multiple failures. The display blanks for one second between faults. These are the TCAS fault codes:

• OK - no failure

• TP - TCAS computer failed

• T1 - top antenna element 1 failed

• T2 - top antenna element 2 failed

• T3 - top antenna element 3 failed

• T4 - top antenna element 4 failed

• B1 - bottom antenna element 1 failed

• B2 - bottom antenna element 2 failed

• B3 - bottom antenna element 3 failed

• B4 - bottom antenna element 4 failed

• X1 - ATC transponder 1 failed

• X2 - ATC transponder 2 failed

• RA - radio altimeters 1 and 2 failed

• PT - pitch data from ADIRU failed

• RL - roll data from ADIRU failed

• HD - heading data from ADIRU failed

• RD - AIs and VSIs failed

• PP - program pins changed from initial configuration

• SP - suppression bus failed

• AG - air/ground input failed or the airplane shows it is on the ground while the radio altimeters show above 1000 feet.

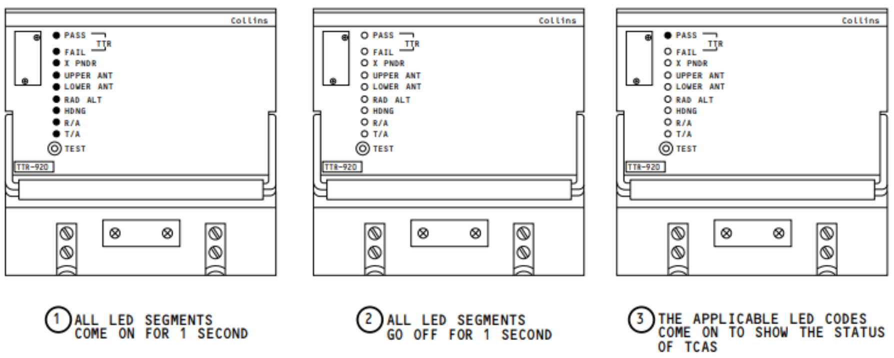


Figure 3.9 TCAS self testing indicators on front pannel

3.4. Efficiency of TCAS operation

The main reason of TCAS implementation was preventing mid-air collisions. Some incidents are provided, in which we saw usage of TCAS functions for preventing collision avoidance:

A310 / B736, was on-route in Southern Norway on 21 February 2001, was on 10 nm norther from Oslo Airport and by a climbing A310 led to loss of separation with an Boeing 737-600 for which response was from a TCAS RA by the Airbus 310 and wasnt following orders in accordance with its possible activation (descend). The Boeing 737-600 received and properly followed a Climb RA.

A319 and PRM1 were on-route, near Fribourg Switzerland on 10 June 2011 when ATC mistaken comand put a German Wings Airbus319 and a Hahn Air Raytheon 390 on same flight tracks over Switzerland and a coordination of TCAS RA followed. After that aircraft both passed each other in close proximity don't having either of them sighting the other aircraft after the one air crew, followed to command procedures, proceeded an ATC descent clearance given by during their TCAS 'Climb' RA instead of than continuing to fly the RA. The Investigation didn't find no explanation for pilots this action by the experienced aircraft crew management pilots. The recorded CPA was about to be 0.6 nm horizontally at height of 50 feet vertically.)

A320 / B738, on-route, near Córdoba Spain, 2014 On October 30, 2014, the descending Airbus A320 closed distance to the Boeing 737-800 at FL 220 after crew of the A320 crew significantly exceeded limiting the maximum sink rate speed of 2000 feet per minute previously showed using indicators, showing that it no longer applies in case it didn't repeated during the re-authorization using lower level. Response to the TCAS RA request made by computer for a descent of no more than 1000 feet per winning minute was to increase it further bigger from 3200 feet per minute. Investigation nessesary found, that in the end it because turned out that while the TCAS A320 equipment on board was working properly, the crew denied commands that it had not followed its original RA properly.

On October 30, 2014, an Airbus A320 landing aircraft significantly increased its previously indicated maximum landing speed of 2,000 fpm. After crossing, approached a Boeing 737-800 near FL220, the altitude was lower. Their response to TCASRA, which should drop below 1,000 fpm, was another increase of 3,200 fpm. The lack of notice delayed the start further of the independent investigation, but it eventually denied the A320 TCAS equipment was available, but the crew did not properly follow the first RA.

On September 2, 2013, A320s and B738s near Delhi, India, deviated from the ATC approach as it became increasingly clear that A320s departing from the same runway would not be in time for landing clearance whe it will be issued. They began to turn over the threshold and then conflicted with the A320 twice. Both climbed similar paths without protection from ATC collisions, initially below the altitude at which TCAS RA operates. As a result of the investigation, the dispute was due to ATC, but it was because both ATC and the flight attendants could not jointly and effectively deal with the investigation results.

The B752 and B752 were on the road north of Tenerife, Spain on November 20, 2011, and had problems reading the altitude label on the ATC radar-controlled display, causing the Finnair Boeing 757 to evacuate and disembark. Thomas Cook Boeing 757 with VMC. The tuned TCAS RA was set up on both aircraft, but as Finnair continued to descend without responding to the ascending RA, the other aircraft that responded correctly to the first RA received more RAs and landed. Finnair aircraft reported maintaining visual contact with other aircraft for a long time.

C525 and B773, near London, July 27, 2009, Cessna 525 leaving London, unable to comply with initial altitudes of 3,000 feet from the QNH SID stop and 4,000 feet at QNH per day, VMC We are approaching convergence. An almost mutually exclusive boundary of the Boeing 777-300ER. The trained crew of 777 did not comply with any of the three agreements established by TCAS. The actual minimum spacing was estimated to be approximately 0.5 nm horizontally and between 100 and 200 feet vertically. It was noted that Cessna gained a gradual increase in SID.

DH8A and DH8C, in the air of Northern Canada, February 7, 2011 Two Air Inuit DHC8s confronted in the middle of Class I non-radar airspace on the east coast of Hudson Bay. Airplane towards other levels set to the level below 1,000 feet. Subsequent investigations used improper FD mode to maintain the assigned level of distorted aircraft and installed it on the aircraft of the DHC8 fleet, as well as operator defects in both TCAS pilot training and aircraft defect reporting. He pointed out the inconsistency of the altitude warning system.

On October 14, 2016, DH8D and DH8D near Sudbury, Ontario, Canada, two Bombardier DHC8-400s disembarked inland near the uncontrolled airfield Sudbury. I received the adjusted TCAS RA because was doing it. It emerged from one cloudy layer and the other was at a level below that layer shortly after leaving. Both crew members ignored the RA and, by optical manipulation, reached a distance of 0.4 nanometers at the same heights. Investigation has shown that a collision occurred in Class "E" airspace after the departing aircraft canceled the IFR to avoid departure delays due to inbound IFR.

F100 and EC45, near Bern, Switzerland, May 24, 2012, visible Fokker 100 landing in the direction of Bern, EC145 helicopter passing through Bern CTR (Class D airspace), VFR horizontally Reached within 75 feet vertically at 0.7 nm. There was early advice on the two aircraft. The investigation was due to the F100's crew failing to perform either the initial

TCAS RA or subsequent reviews, and the TCAS was installed system in Bern but disabled "years ago". It turned out that it was done.

F900 and B772, on the way, near Estonia, Kinoshima, October 17, 2013, cleared Falcon 900 ascended to FL340 and operated as a government aircraft equipped with TCAS II v7.0. As a result, in FL 350 on VMC day, it was lost in the opposite direction of the indicated class and the scheduled class. As a result of the investigation, it was concluded that the F900 crew received the TCAS RA "ADJUST VERTICAL SPEED" and started the climb when a low climb rate of 800 fpm was required. Safety recommendations have been made regarding the TCASRA requirements for state aircraft.

GLF5 and A319, Southeastern France, on September 16, 2004, a separation loss occurred between the Air France A319 and Gulfstream 5 and landed on a tuned TCAS RA that neither aircraft followed without ATC's permission. [15]

As you can see, in all these incidents after the other aircraft entered the TCAS bypass area, the traffic advisory (TA) mode was switched to the resolution advisory (RA), both other aircraft issued the corresponding commands, for both crews. A collision occurred when the RA command wasn’t followed. It was avoided when they are followed by both crews. However, if the pilot decides not to follow the RA command or goes in the wrong direction and both aircraft are equivalent to TCAS II version 7.1, the sense reversal feature will work.

In this case, TCAS collision avoidance will not work if the competing pilot disables TCAS and flies without it.

But even after a TCAS was implementated of collision between TCAS-equiped commercial airliners and general aircraft are happening.

After TU-154 and Boeing 757-200 mid-air collision at Uberlingen Germany on 1st July 2002 happened, in which despite the fact that TCAS system was installed on both plane, mid-air collision happened. They collided after pilots of TU-154 followed ATC order to decent instead of TCAS RA order to climb, while Boeing 752 pilot was following prioritized TCAS RA orders to descent. After this incident TCAS II Version 7.1 was created and TCAS RA commands made priorityzed over ATC instructions. One year before mid-air collision in Germany, similar incident happened in Japan airspace, but planes collision was prevented. Both planes passed each other within 135m.

Before making TCAS system mandatory, in 1996 happened Charkhi Dadri mid-air collision over New Delhi. Many factors led to this incident, one of which is that both planes weren't equipped with the TCAS system. Mandatory worldwide implementation of TCAS system began after incident. Before TCAS system was implemented, mid-air collision were very big issue problem, because air traffic controllers were overload and couldn't proceed all planes flights, pilots mistakes, bad visibility in the sky, technical issues, pilots disorientation in space and many other reasons.

Conclution to chapter

This chapter showed TCAS systems made by different suppliers: Garmin, Rockwell Collins, Honeywell and ACSS.

Rockwell Collins produces TTR-94-94D and TTR-2100

TTR-94-94D can be equiped on business jets and used on regional airliners. It has compatiblility with ADS-B standart

TTR-2100 is made as replacement for TTR-94-94D system. It integrated with the Integrated Surveillance System (ISS-2100) used on the Boeing 787 Dreamliner, which merges in one system weather radar, TCAS transponder and terrain awareness integrated. It meets the requirments for ADS-B standart

Honeywell can offer CAS67A system family of TPA-100 system units, wih TPA-100A/B serving being a direct replacement for TPA-81A. Aircraft modification does not required for TPA-100A, but it only can use Version 7.0. TPA-100B has same functions as TPA-100A, but can use TCAS II Version 7.1. TPA-100C uses ADS-B function. Its main advantage is range: without operating of ADS-B TCAS surveillance can reach up to 120 nmi range, and when ADS-B IN used range can be up to 250 nmi. TPA-100 family has compatibility with Airbus aircrafts including A320 family and A330.

TCAS-2000 system offerred by ACSS, and considered as most common wersion of TCAS in the world. Its compatible with Version 7.1 and has the ADS-B support.

Efficiency of TCAS operation was considered in this chapter. Statistics says that 49% of mid-air collision can occurre during approach or departure from the airport. Another 51% can appearee while route climbing or descending and cruise. During most incidents, after receiving initial RA pilots reacted to it, and actions were taken to prevent collision.

Sometimes, pilots don't follow TCAS RA orders for collision avoidance, that's why RA reversal was implemented to prevent mid air collision. In most of considered cases mid air collisions were prevented by using TCAS system. RA reversals were developed and implemented after 2002 mid-air collision between TU-154 and B752 in Germany, during which pilot of TU-154 instead of following TCAS RA command they followed ATC instructions.

In 1996 Charkhi Dadri mid-air collision was worldwide precedent which caused implementation of TCAS system around the globe.

CONCLUTION

This graduation work considered operation of Traffic Collision Avoidance System (TCAS). Its following version used at aircrafts are passive, TCAS I and TCAS II. Systems like passive and TCAS I are considered to be used for small aviation. Commercial aviation uses TCAS II systems. The main proposed new ACAS standart for future use is called ACAS X, and is expected to be avaible in 2020s. The same equipment as TCAS II will be used for ACAS X for faster transition for usisnf of newer system. It considered to be compatible with UAVs, due to their spreading worldwide, for reducing chance for collision with human controlled air traffic. For now, we only use TCAS II Version 7.1 worldwide.

TCAS II made from following elements: TCAS CPU, transponder in mode S, Mode S/TCAS Control Pannel, antennas and cockpit displays (traffic display and the RA display). Displays have different implementation ways, including using them as a single unit. But no matter of implementations of these displays, information provided stays the same. Traffic display shows information about own aircraft location and placement of other traffic. The following information provided about other traffic planes: distance, relative height different and bearing. A filled yellow circle indication shows planes which causesing issuance of TA. A filled red square shows planes, which caused usage of RA. An unfilled white or cyan diamond is used for displaying non-threat traffic. A filled white or cyan diamond is used for displaying proximate traffic. TCAS RA display in most cases implemented as part of an IVSI display or on a PFD.

TCAS computer unit is utilizes following TCAS functions: airspace survelliance, intruder tracking, threat detection, generation of advisories and RA maneuver. CPU of TCAS computer uses data from systems installed on-board of an aircraft: radar and pressure altitude, discrete aircraft status imputs. It also used as coordination of avoidance maneuvering with the treat aircraft.

For TCAS II operation it is necessary for TCAS transponders to be installed and operational. It uses coordinations with other aircraft equipped with TCAS, for Ras proper issuence.

The following collision avoidance concepts are used for TCAS operations sensitivity level, protected volume and tau.

Done in this work marketing research of different system avaible for installation of Traffic Collision Avoidance System showed, thet the most efficient from all modern systems are following systems: TCAS-2000 and TPA-100C. They have ADS-B protocols support compatibility and uses current TCAS Version 7.1.

One of the biggest advantages of TPA-100C systems is the range: without utilizing ADS-B protocol mode surveillance and utilizing only TCAS mode is up to 120 nmi range, and while using ADS-B IN functionality its range can get up to 250 nmi.

The TCAS 2000 system can give pilots with highest bearing accuracy (2˚ vs. 9˚ for standard TSO systematic specification requirements) and has extended range of survilance (up to 80 nautical miles / 148 km using active mode and distance greater than 100 nautical miles / 185 km utilizing passive mode), which are available nowdays.

TCAS 2000 has another advantage and it is its popularity. Over 10,000 TCAS 2000 computer units are delivered and used by worldwide operators. TCAS 2000 systems can be offered by most OEM manufactorers, with companies like Boeing and Airbus also uses this system.

Amplitude monopulse sensing offers uses and gives significant user benefits, such as insensitivity to cable length disparity giving of up to 7 feet and tolerance to different off-frequency replies. The ACSS amplitude monopulse TCAS operational system provides instant 360-degree signal, which can be recepted with no scanning provided thus allowing for rapid intruder fastest acquisition and maximum time of warning.

TCAS-2000 has bigger and increased reliability functions compared to previous TCAS II generation systems, thus saving bigger maintanence costs for airliners. TCAS-2000 has storage for internal data recorder with utilizing it as analysis tool based on PC. It also can give user functions of performing on-board software update.

Both TCAS 2000 and TPA-100C systems utilizes support for ADS-B, by this can giving increased range better of survelliance. TCAS-2000 utilizes range up to 80nmi in survelliance in mode S, while TPA-100C has up to 120nmi. Utilizing ADS-B survelliance mode of TCAS-2000 system has range more then 100nmi, allowing earlier intruder detection while TPA-100C – up to 250nmi.

Comparing these both systems, we can say that TCAS-2000 is more common system and their functions have amplitude monopulse system, which helps user and provides instantaneous 360-degree signal recaption without initializing scaning, thus allowing faster and earlier intruder acquisition, while TPA-100C have bigger survelliance and safety zone utilizing both modes – mode S and ADS-B.

Version 7.1 has high level of aircraft protection, but despite that, there are still chances mid-air collision, because not every aircraft is equipped and can't be fitted with this system, and thus still giving a chance for occurance of mid-air collision. Another disadvantage of current version is quantity of unnesesary advisories, which can distract pilots from flying. Future versions can fix these problems and most of them will be resolved while ACAS X standart will be implemented which utilizes differen logic of operation. It designed to reduce number of unnecessary advisories while it will maintain same level of protection. ACAS X also considered to be implemented on unmanned vehicles and will be used in light aviation, with this increasing number of planes with TCAS equipped.

One variant of TCAS system will be adapted on operating principle based on flight trajectory which can give better collision avoidance logic.

Obviously, that TCAS must be mandatory for airlines to be equipped on their planes also with systems utilizing most recent versions of collision avoidance logical systems for more safer operational principle and for airline for having reputation as reliable carrier. Operation of aircraft without collision avoidance systems can be very dangerous in modern conditions due to air traffic density in some regions.

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