TCAS II ON HELICOPTERS
BREAKING THE MYTH

INTRODUCTION

A Traffic Collision Avoidance System (TCAS) II is one implementation of the systems that is generically known as an Aircraft Collision Avoidance System (ACAS). It is system designed to reduce the occurrence of a mid-air collision by monitoring adjacent aircraft fitted with transponders and alerting the crew if certain thresholds are breached. The system is independent of air traffic control or other ground based systems.

TCAS began as a FAA initiative and was developed from the 1950s to the 1970s. In the early 1980s The USA Congress issued a mandate for an aircraft collision avoidance system. The FAA developed the standards for TCAS for regulators via ICAO and for manufacturers via the RTCA.

A TCAS II system provides both Traffic Advisory (TA) information and Resolution Advisory (RA): the former being a warning to the crew of adjacent traffic; the latter being guidance on avoiding a collision by commanding a manoeuvre in the vertical plane. TCAS I systems currently fitted to some helicopters can only provide TA information.

TCAS II fitted to fixed wing aircraft has proved to be a significant safety enhancement and is now mandated in Europe for all public transport aircraft weighing more than 5.7 tonnes or carrying more than 19 passengers.

BACKGROUND

Why Not Fit TCAS II?

There was a general perception**,** supported by some in the Regulating Authorities that TCAS II would not work on helicopter and in fact could be detrimental to fixed wing TCAS II systems. Some of the arguments raised were:

- TCAS II algorithms would not cope at low (<100 kt) airspeeds.
- The main gearbox and rotors would degrade the TCAS II antenna patterns.
- Helicopters are incapable of meeting the RA profiles, in particular the requirements of a climb RA
- If a large number of helicopters were operating in an area, this would increase the traffic density and possibly degrade the range of fixed wing TCAS II systems. Please see the technical description below.
- Helicopter profiles, such as winching and underslung load work are outwith the considerations in the TCAS II MOPS.

The Problem

Helicopters, particularly those operating in support of oil and gas exploitation around the world, have been subjected to a large number of AIRPROX in recent years. This is due to the operating environment, normally in unregulated (Class G) airspace with limited or non existent radar services. In an attempt to reduce the risk of collision a number of manufacturers and operators fitted TCAS I, as it was generally believed that TCAS II would not work on helicopters. Additionally, the operational regulations governing commercial air transport helicopters in Europe, namely JAR OPS 3, specifically stated that TCAS II would not work on helicopters[1]. Unfortunately TCAS I systems mandate that the crew sight the intruder aircraft before manoeuvring in accordance with the Rules of the Air and so are not suitable in IMC, at night or where the intruder comes from a blind arc, such as the rear.

This AIRPROX from 2004 was a catalyst for a number of safety initiatives, including the investigation of fitting TCAS II to helicopters.

AIRPROX REPORT No 008/04

After departing the AUK 'A' platform at 0907 they climbed to 1000ft McCabe RPS (999mb) and joined the 117° radial at 140DME from ADN - the usual transit altitude for this route is 2000ft or the appropriate flight level, but they selected a lower altitude because of strong (55kt) adverse winds. As they were approaching 119nm range from the ADN VOR, in level cruise heading 285° at 125kt with autopilot engaged, they suddenly became aware of a *"roaring"* noise coupled, "*milliseconds later*" by the sudden onset of harsh and severe turbulence which started with a roll and yaw to the right. The P1 grabbed the controls and looked left, across the cockpit toward the ac's 10-10:30 position and saw the P2's windscreen and quarter light filled with what they thought was the underneath of the rear section of a Tornado in a steeply banked turn away from the helicopter at a range of about 50ft. The Tornado then reversed the turn and passed ahead before climbing away toward the NW. No avoiding action was taken as the other ac had passed; he assessed the risk as *"high"* and added that the jet had closed unseen from their 8 o'clock. The Airprox was reported to Aberdeen ATC immediately after level flight was regained.

AIRPROX Report 154/06 showed the need for TCAS II even when operating under a radar service. In this case a Super Puma and Nimrod aircraft were only separated by 200 ft vertically when their radar returns merged on the radar screen. This AIRPOX occurred due to a breakdown in coordination between two ATC units which resulted in conflicting clearances being given to the two aircraft involved.

Due to the unsuitability of TCAS I for IFR operations, a study was undertaken to evaluate if TCAS II could be fitted to a helicopter, despite the statement in JAR OPS 3. An initial study found no

[1] ACJ OPS 3.398

reason why TCAS II should not function correctly when fitted to a helicopter and so a trial was proposed. At this point Rockwell-Collins offered use of equipment and technical assistance with the trial installation. Shell Aircraft Inc provided some funding for the design work.

TECHNICAL DESCRIPTION

The Minimum Operational Performance Standards for TCAS II version 7 are detailed in DO 185A.

The TCAS II system monitors the airspace surrounding the aircraft by interrogating the transponders of other aircraft. Replies to the interrogation enables TCAS II to compute, at 1 Hz, the following information:

- Range of intruding aircraft from own aircraft.
- Relative bearing to the intruder.
- Altitude and vertical speed of the intruder, if it is reporting altitude.
- Closing rate between the intruder and own aircraft.

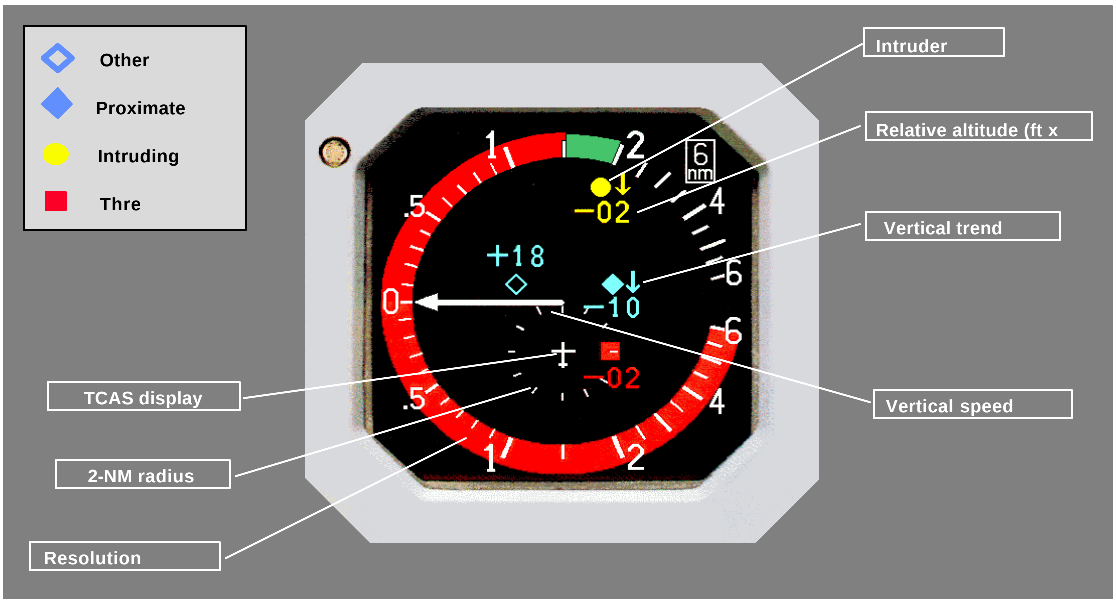
Using this data TCAS II predicts the time to, and the separation at, the intruder's Closest Point of Approach (CPA). Should TCAS II predict that certain safe boundaries may be violated, it will issue a Traffic Advisory (TA) to alert the crew that closing traffic is in the vicinity.

If the intruder continues to close, TCAS II will issue a Resolution Advisory (RA) to obtain or maintain safe vertical separation between own aircraft and the intruder. TCAS II bases the alarms on a five second crew reaction time to begin the separation manoeuvre: increase or reversal of an RA requires a reaction in two and one half seconds. It should be noted that time (Tau) to CPA is normally used to determine when to issue a TA or RA as this takes into account closure rate. When the closure rate is low (such as being overtaken by a slightly faster aircraft) and hence time to CPA less predictable, a DMOD function ensures an appropriate alert when certain range boundaries are crossed.

The crew is provided with:

- A traffic display that indicates the approximate bearing, range and relative altitude of nearby transponder equipped aircraft. The traffic display symbology indicates to the crew other traffic, proximate traffic, aircraft generating a TA and aircraft generating a RA.
- Associated with TAs and RAs are aural warnings.
- When a RA is generated the crew is provided with a display showing the vertical manoeuvre required to avoid a collision.

Image 1: Analogue TCAS II display showing the traffic display and Climb RA.



The specification of TCAS II requires that it provides reliable surveillance out to a range of 14 nm, but longer ranges are often provided in low traffic densities. For en-route airspace, the maximum intruder relative closing speed for TCAS II is 1200 knots. Applying the threat logic parameters in DO 185A, the longest range at which TCAS II will be required to generate a RA is 11.67 nm. TCAS II provides reliable aircraft collision warning in aircraft densities up to 24 transponder equipped aircraft within 5 nm of the TCAS II aircraft (0.3 transponder equipped aircraft per nm^2). With traffic densities greater than 0.3 aircraft per nm^2 TCAS II provides protection from other aircraft having a closing speed up to 500 kt: with an aircraft density of 0.06 transponder equipped aircraft per nm^2 or less protection from relative closing speed up to 1200 kts is provided.

The Logic of an Encounter. The equipment determines the approximate bearing of intruder aircraft. Bearing estimates are used by the collision avoidance algorithms to determine the horizontal miss distance at the closest point of approach (CPA); if the miss distance is below a specified threshold and the vertical separation also broaches a specified threshold then a TA is generated. If the intruder continues to close then approximately 15 seconds after the TA is issued, a RA is generated.

The purpose of the TA is to:

- Alert the crew to the potential threat traffic and provides intruder position data so that the crew can attempt to visually acquire the threatening aircraft.
- Prepare the crew for an RA as it provides a graphical display of the conflict and reduces the crew's reaction time in responding to a RA.

When both aircraft involved in the conflict are TCAS II equipped, then the units communicate via the Mode S transponder to coordinate the RA issued to the aircraft in the encounter.

Thresholds

The following thresholds are used to generate TA and RAs:

Table 1: Tau and DMOD Threshold for Initiating Advisories

Own Altitude (ft)	Tau (seconds)		DMOD (nm)	
	TA	RA	TA	RA
<1000	20	N/A	0.30	N/A
1000 – 2350	25	15	0.33	0.20
2350 – 5000	30	20	0.48	0.35
5000 - 10000	40	25	0.75	0.55

Operational Rules

ICAO PANS-OPS 8168 states that:

- The pilot <u>may depart</u> from the ATC clearance (or refuse it) to follow an RA
- The pilot must comply with his airline operational instructions. The pilot always retains the ultimate responsibility for his flight
- Following an RA is similar to an ordinary evasive manoeuvre: the use of TCAS does not alter respective responsibilities of pilots and controllers

ICAO PANS-ATM 4444 states that:

- Following an RA is similar to an ordinary evasive manoeuvre: the use of TCAS does not alter the respective responsibilities of pilots and controllers:
- The controller is no longer responsible for separations during a deviation due to a response to an RA
- "*When a pilot reports a manoeuvre induced by an ACAS resolution advisory, the controller shall not attempt to modify the aircraft flight path [...] but shall provide traffic information as appropriate*"

In Europe, the operational training and pilot procedures are covered in JAA Temporary Guidance Leaflet 11 (TGL 11).

Inhibits

TCAS II is not able to provide RAs under all conditions and so some inhibits are required, as shown in Table 2:

Table 2: Cases when TCAS II is inhibited

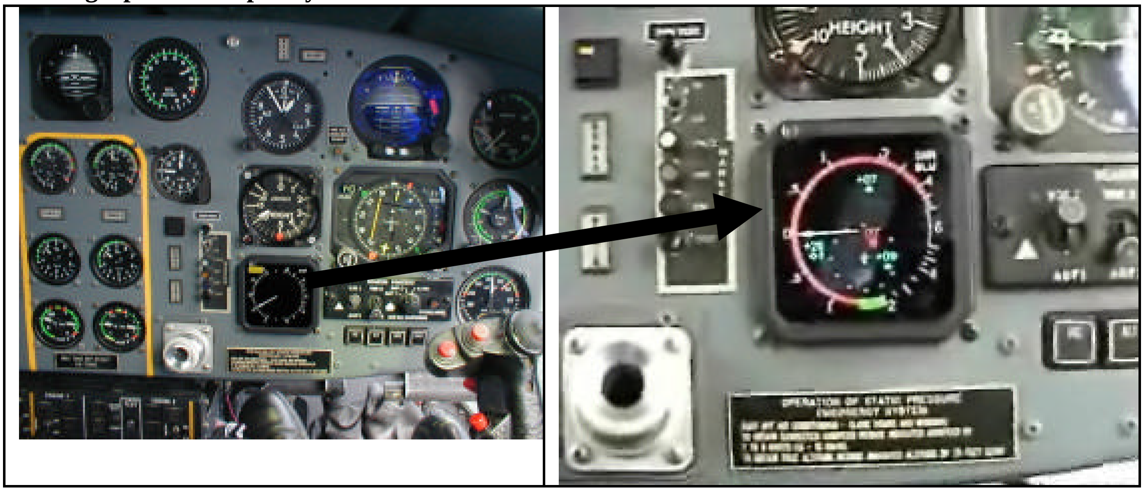
ADVISORY OR MODE	LIMITS
Increase Descent RA	Prevented below 1550 ft AGL during a climb and 1450 during a descent.
Descend RA	Prevented below 1000 ft AGL during a descent and below 1200 ft AGL during a climb.
Resolution Advisories	Prevented below 1100 ft AGL during a climb and below 900 ft AGL during a descent. (TCAS automatically changes to the TA or TA ONLY mode).
TA Audio Annunciation	Prevented below 600 ft AGL during a climb and below 400 ft during a descent.
Climb Command	Prevented in some flight configurations of the aircraft.

TRIAL INSTALLATION

Photograph 1: The first helicopter in the world certified with TCAS II

The Bristow Design Office designed a TCAS II installation for G-TIGE under its EASA Part 21 Approval. The design used an off-the-shelf Rockwell-Collins TCAS II 4000 system. The TCAS II traffic and RA displays are shown on a TVI 920 display which replaced the standard VSI.

Photograph 2: Cockpit layout



Ground & Flight Tests

As no certification material applicable to TCAS II installation on helicopters existed, it was agreed with The Certification Authority that fixed wing Guidance Material in AC 20-151 could be applied.

Although AC 20-151 does not mandate flight tests for TCAS II on aeroplanes, it was decided from the outset that a series of ground and flight test would be conducted to ensure the correct functioning of the system.

The ground tests aimed to investigate any blind spots caused by blanking from the rotors and transmissions: following the successful completion of which flight testing commenced. The ground tests aimed to investigate any blind spots caused by blanking from the rotors and transmissions: following the successful completion of which flight testing commenced.

Flight 1 used another helicopter as a threat aircraft. This flight had a number of objectives:

- Confirm that no blind spots existed due to blanking from the rotors and transmission.
- Measure the distance between aircraft when TAs and RAs were generated. Knowing the relative helicopter velocities then permitted the Tau value at which the advisories were issued to be checked against the standards.
- Confirm that very low closure speeds would still generate advisories using the DMOD function.

Flight 1 successfully and achieved all its objectives.

Flight 2 used a TCAS II equipped BAe 146 as the threat aircraft. This flight had the following objectives:

- Confirm the TCAS II RA coordination occurred during encounters.
- Confirm that the helicopter TCAS II system continued to function at higher closing speeds.
- Measure the distance between aircraft when TAs and RAs were generated. Knowing the relative aircraft velocities then permitted the Tau value at which the advisories were issued to be checked against the standards.

Flight 2 was also successful achieving all the test objectives.

Flight 3 included members of the CAA Flight Test Department, representing EASA, and aimed to confirm that the Super Puma could meet the Climb RA criteria at maximum all-up mass at representative altitudes. With its successful completion, the formal flight test phase reached its conclusion

Equipment Qualification

Following the successful flight testing, Rockwell-Collins qualified their units in accordance with the vibration frequency spectrum specified in DO 160D. The TSO was received in late 2007.

Supplementary Type Certificate

An application had previously been made by the Bristow Design Office to EASA for a Supplementary Type Certificate for the installation and the certification basis agreed. Thus on successful completion of the flight tests and achievement of the Rockwell-Collins TSO, all the design and test paperwork was submitted to the UK CAA, acting on behalf of EASA in January 2008. Following processing of the STC, a Technical Visa permitting operations with TCAS II was issued in April 2008 pending issue of the final STC.

THE NEXT STEP

Shortly before receipt of the Technical Visa pilots were trained in accordance with the requirements of TGL 11. After receipt of the Technical Visa commercial operations with TCAS II functioning were commenced. In order to gather data, crews are asked to complete a questionnaire following each flight and this, together with supporting information from Flight Data Monitoring (HOMP), is used to develop our in-depth understanding of system functionality.

Work has already commenced on fitting TCAS II to additional AS 332Ls, design work has commenced on other aircraft types and soon helicopter TCAS II will lose its rarity.

***'The myth is broken'*.**

Abbreviations

TA - Traffic Advisory. TAs indicate the approximate position relative to the aircraft, either in azimuth only, or azimuth and altitude, of nearby transponding aircraft which may become a threat.

RA – Resolution Advisory. RAs recommend manoeuvres or manoeuvre restrictions in the vertical plane to resolve conflicts with aircraft transponding altitude.

CPA – Closest Point of Approach

Tau – Tau is an approximation of the time, in seconds, to CPA or the aircraft being at the same altitude. This is the primary means of triggering a TA or RA

DMOD – Distance Modulation. Used to trigger TAs and RAs when closure rates are very slow.