Department of Transport and Regional Development

Bureau of Air Safety Investigation

INFORMATION PAPER

TCAS in Australia

BASI
Bureau of Air Safety Investigation

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CONTENTS

ABBREVIATIONS

ACAS	Airborne Collision Avoidance Systems
AIC	Aeronautical Information Circular
ATC	Air Traffic Control
BASI	Bureau of Air Safety Investigation
B737	Boeing 737
B747	Boeing 747
B767	Boeing 767
CAA	Civil Aviation Authority (Airservices Australia since 6 July 1995)
CASA	Civil Aviation Safety Authority
E110	Embraer E110
FK50	Fokker 50
FL	Flight Level
GA	General Aviation
IMC	Instrument Meteorological Conditions
IR	Interim Recommendation
MD11	McDonnell MD11
NM	Nautical Miles
PA31	Piper PA 31
RA	Resolution Advisory
RPT	Regular Public Transport
SID	Standard Instrument Departure
SRD	Standard Radar Departure
SSR	Secondary Surveillance Radar
STAR	Standard Instrument Arrival Route
TA	Traffic Advisory
TCAS I	Traffic alert and Collision Avoidance Systems, Version One
TCAS II	Traffic alert and Collision Avoidance Systems, Version Two
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

SUMMARY

The carriage of traffic collision avoidance system (TCAS) equipment is not mandatory in Australian aircraft. However, many Australian and foreign registered aircraft operating in Australian controlled airspace are equipped with TCAS because of their compliance with a US requirement when operating in American airspace.

A total of 157 TCAS-related air safety occurrences were reported in Australian airspace during 1993 and 1994. The circumstances of these events, and the views of the pilots and air traffic controllers involved in the occurrences, were examined in detail.

Early versions of TCAS produced nuisance or unnecessary warnings, but later software has almost eliminated these problems. TCAS has had a positive safety benefit in Australia and is considered to be a valuable additional safety net in the Air Traffic Services system.

In June 1995, following a serious breakdown of separation between two passenger jets, BASI made a wide-ranging recommendation to the Civil Aviation Authority (CAA), calling for the fitment of airborne collision avoidance systems to all aircraft engaged in regular public transport (RPT) operations. In November 1996, the Civil Aviation Safety Authority (CASA) released a legislative instrument proposal dealing with the introduction of TCAS equipment to certain commercial transport aeroplanes.

INTRODUCTION

1.1 Background

In the three years 1992–1994, there were 152 reported loss of separation occurrences in Australian controlled airspace which involved at least one commercial passenger aircraft.

The continuing incidence of such occurrences and the inherent limitations of the 'see-and-avoid' techniques for aircraft separation, indicate a need for improved defences against mid-air collision. There has been considerable worldwide interest in collision prevention systems which utilise radar beacon transponders routinely carried by aircraft. Several acronyms have been used to refer to such systems. The International Civil Aviation Organisation adopted the generic term 'airborne collision avoidance system' (ACAS); however, the term 'traffic alert and collision avoidance system' (TCAS), referring to the ACAS system developed in the USA, is now more widely used.

TCAS

The Federal Aviation Administration in the USA provided the impetus to develop, test and install TCAS systems in airline aircraft by late 1992. The introduction of TCAS into operational service within the USA was jointly oversighted by the US aviation industry and the Federal Aviation Administration, and included participation by a number of airlines.

There are currently two versions of TCAS in operational use: TCAS I and TCAS II. Both versions provide the pilot with a cockpit display indicating the presence of a transponding

'intruder'.* TCAS I equipment warns of potential conflicts by providing a traffic advisory (TA). In addition to TAs, TCAS II equipment also provides a second level of alert, termed a resolution advisory (RA). This alert directs the flight crew to make a vertical manoeuvre to avoid the intruding aircraft.

In the USA, TCAS I or TCAS II systems must be fitted to turbine powered aircraft carrying between 10 and 30 passenger seats. A TCAS II system must be fitted to aircraft carrying more than 30 passenger seats.

Implementation problems in the USA

Despite generally positive results, a number of problems were experienced with the implementation of TCAS in the USA. These problems included:

- Occasions when the instructions given by an air traffic controller and TCAS were in conflict.
- Pilots executing excessive vertical manoeuvres in response to RAs resulting in possible conflict with other aircraft, particularly in holding patterns.
- Spurious TCAS alerts generated when TCAS-equipped aircraft operated in the vicinity of SSR remote ground calibration units or military installations.
- Reversal of a TCAS RA climb or descent command when the 'intruder' aircraft's flight profile was modified.
- TCAS alerts generated in situations where legitimate GA activity and VFR air routes were in close proximity to terminal approach and departure paths.

The Federal Aviation Administration found, very late into the implementation program, that controllers were not sufficiently aware of the operational implications of TCAS. In particular, controllers needed a better understanding of flight crew reactions to TA and RA events and the likely vertical magnitude of altitude excursions when an aircraft responded to a RA. Consequently, the Federal Aviation Administration undertook an air traffic service education program and instituted procedural methods to identify TCAS-equipped aircraft to the controller.

The initial software logic versions of TCAS II generated an undesirable number of TA and RA events which were classified as 'unnecessary' or 'nuisance'. Updated logic versions 6.02, 6.04, and then 6.04A were developed to reduce these events.

TCAS in the Australian ATS system

Since TCAS equipment was mandated in the United States, an increasing number of foreign and Australian TCAS-equipped aircraft have been operating in Australian airspace. Consequently, BASI received notifications of TCAS-related air safety occurrences in 1993, and continues to receive reports.

In June 1995, BASI recommended that the then CAA mandate the fitment of airborne collision avoidance equipment in aircraft engaged in regular public transport operations. This recommendation was made in response to a serious occurrence involving two jet aircraft in which TCAS was instrumental in preventing a mid-air collision.

To date there has been no systematic evaluation of the effectiveness of the TCAS system within the Australian environment, or of the influence of TCAS on the Australian air traffic

*An 'intruder' aircraft may, however, be operating legitimately and the term does not imply that the 'intruder' is not in compliance with a clearance.

system. Due to the potential importance of TCAS as an additional safety tool, it was decided to conduct such an investigation.

1.2 Objectives

The research program had the following objectives:

(a) To identify trends and patterns in reported TCAS-related occurrences within Australian airspace.

(b) To identify, where possible, the impact of TCAS-related occurrences upon the Australian ATS system.

1.3 Scope and limitations

This study was limited to TCAS-related occurrences in Australian airspace reported by flight crew and/or Air Traffic Services between 1 January 1993 and 31 December 1994.

Several significant changes occurred during the reporting period. These changes included a variety of educational and awareness measurements introduced by the CAA (now Airservices Australia) for Air Traffic Services personnel throughout the period. There were also a number of changes to the TCAS II software during the study period. In particular, TCAS software was upgraded to logic version 6.04A from May 1994. This upgrade reduced the frequency of TCAS events. One significant feature of the 6.04A modification was that the TCAS TA vertical limit was reduced from a 1,200-ft vertical buffer to approximately 850 ft for aircraft operations below FL300.

The reporting requirements for TCAS events also varied throughout the data collection period. The requirements for notification of TCAS events to BASI as air safety occurrences became effective on 1 October 1993. A TCAS alert notification form similar to that used by the Federal Aviation Administration was provided to industry. TCAS RA events were classified as immediately notifiable occurrences and reporting was mandatory as soon as practicable after the occurrence. TCAS TAs were required to be reported within 48 hours. These air safety incident reporting requirements were made under the provisions of Air Navigation Regulation 274 (1) and applied to Australian registered aircraft in both domestic and international airspace and to all other aircraft operating within Australian controlled airspace.

It should also be noted that the number of aircraft equipped with TCAS II operating in Australian controlled airspace increased during the study period. The TCAS-equipped aircraft which were involved in occurrences were all high capacity transport aircraft.

METHOD

Selection of events

This study included all reported TCAS-related events which occurred in Australian airspace during 1993 and 1994. Reports were received from three sources: firstly, an air traffic controller could have reported the event as an air safety occurrence; secondly, a flight crew could have reported the event as an air safety occurrence; or thirdly, they could have reported the event using a TCAS alert notification form. On most occasions, more than one of these methods was used.

Collection of data

For each TCAS event, basic data were recorded. The basic data included information such as the flight conditions, light conditions, whether the event was a TA or a RA, type of air traffic service provided, and characteristics of the intruder aircraft.

These descriptive data were collected from the ATC incident reports, the flight crew incident reports, and/or the flight crew TCAS alert notification forms (see appendix 1).

Opinion data

In addition to the basic descriptive data, reactions and opinions of the relevant flight crew and air traffic controllers were collected. The flight crew were asked whether they followed the RA (if it occurred), their estimated deviation from their ATC clearance, and their opinion as to whether the RA was 'necessary', 'useful' or 'nuisance'. These questions were included in the TCAS alert notification form.

Telephone interviews were held with the relevant controllers for TCAS occurrences during September, November and December 1994. A specially designed data collection form was used to structure the interview and controllers were asked to comment on such issues as their TCAS awareness training and their understanding of TCAS equipment operation.

RESULTS AND DISCUSSION

3.1 Number and type of events

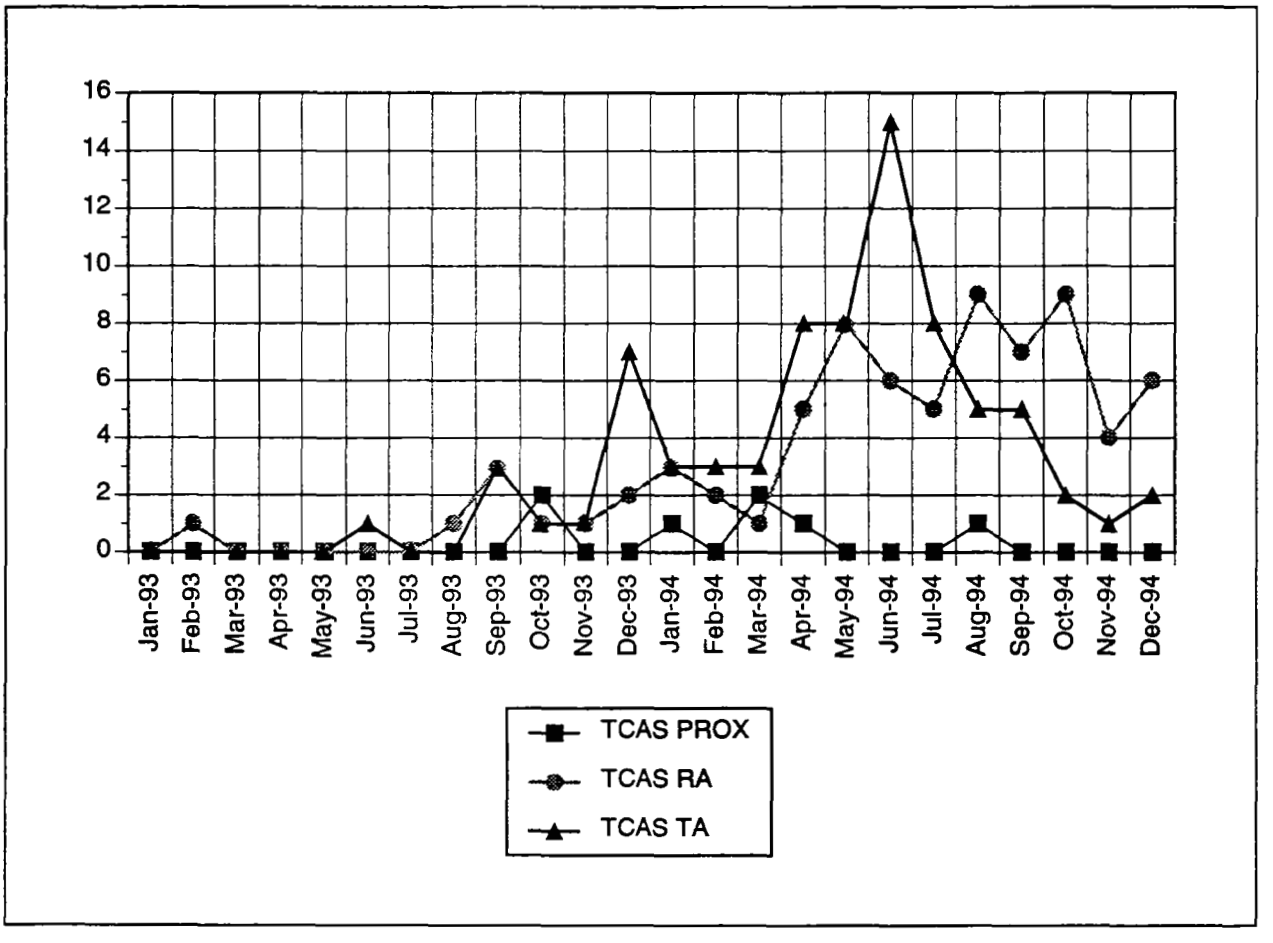
Number of events

There were a total of 157 reported TCAS-related occurrences in Australian airspace during 1993 and 1994. Eleven of these were associated with a loss of separation standards. The number of occurrences by month is presented in figure 1.

In addition to the TCAS occurrences in Australian airspace, there were 58 reports of TCAS occurrences involving Australian registered aircraft in foreign airspace. These occurrences were similar to those in Australian airspace, and they are not analysed further in this report.

FIGURE 1

Frequency and type of TCAS event



Type of TCAS alert

Of the 157 occurrences in Australian airspace, 76 were TA events and 74 were RA events. The remaining seven events were related to traffic proximity signals (that is, visual signals which occur prior to a TA or RA aural alert). The gradual increase in the number of RA events over time is consistent with the increase in the number of aircraft fitted with a TCAS

II system over the period. The decrease in TA events towards the end of 1994 is consistent with the TCAS modifications to the 6.04 software.

Illustrations of TCAS events are given in examples 1–6 below.

EXAMPLE 1

Occurrence number 9400524

3 March 1994 RA Sydney 747-300/Helicopter

VH-EBY received a resolution advisory to monitor vertical speed when on 3-NM final to runway 16. There was a helicopter airworking in the zone at the time, operating not above 1,500 ft. The helicopter was cleared to track to Balmain, passing behind VH-EBY, and was required to maintain its own separation. The exact position of the helicopter when the TCAS warning was received is not known; however, ATS indicated there was no breakdown in separation.

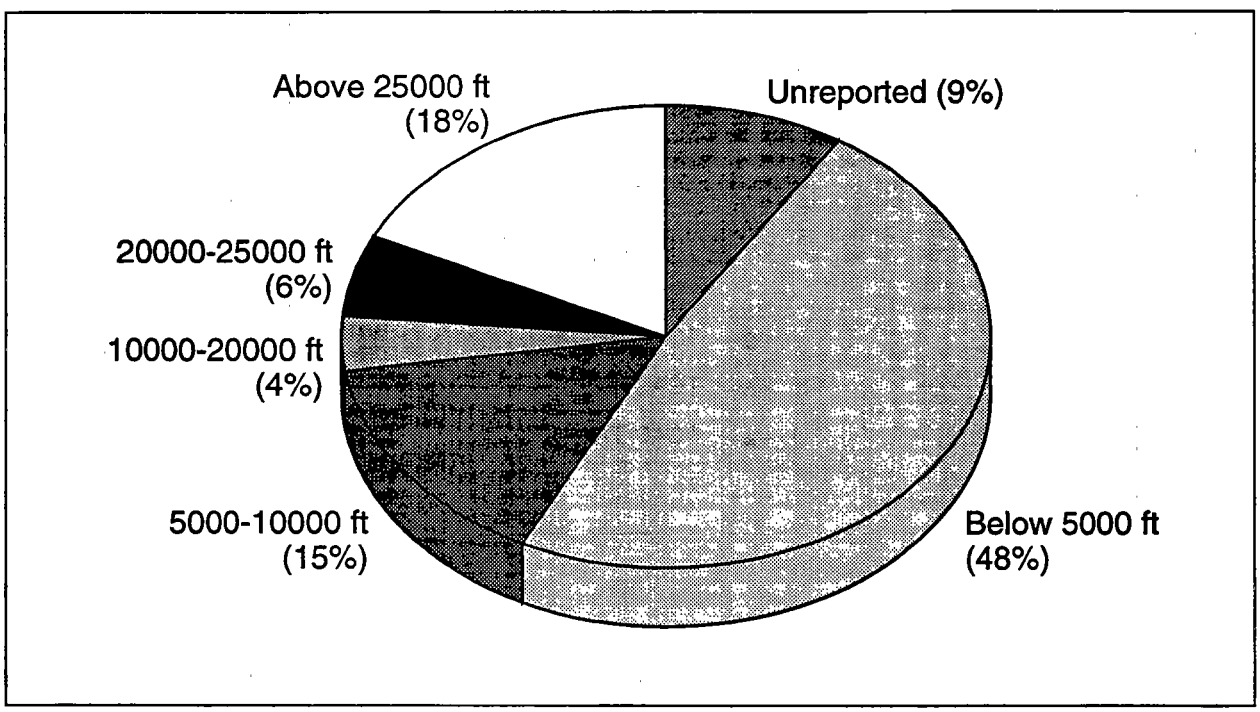
3.2 Location of events

Altitude

Figure 2 presents the altitude bands within which TCAS-related events occurred. As can be seen in the figure, the largest proportion of events occurred below 5,000 ft.

FIGURE 2

Altitude band—TCAS occurrences



EXAMPLE 2

Occurrence number 9400524

22 June 1994 RA Cairns B767-200/Unreported

VH-BXF departed from runway 55 with an instruction to turn right and track to a position west of the aerodrome. VH-EAO (B767-200) departed two minutes later from the same runway following a standard instrument departure which required the aircraft to commence a left turn no later than the departure end of the runway. The crew of VH-EAO had been advised of the flight path of VH-BXF and had this aircraft in sight prior to commencing takeoff. When VH-EAO was turning left after takeoff, a TCAS resolution advice was received on VH-BXF.

Type of airspace

All of the TCAS-related events occurred within controlled airspace. The majority of these events (108, or 69%) occurred within radar coverage with 41 (26%) occurring in procedural airspace. For eight events (5%), the type of airspace was undetermined or unreported.

Almost all of the airspace over the Australian mainland is covered by procedural airspace, as is all the oceanic airspace. The radar coverage is predominantly on the eastern seaboard. As the separation standards applicable to procedural airspace are greater than the radar standards, it was expected that TCAS events would be fewer in the procedural environment.

Nevertheless, the high incidence of TCAS events in radar controlled airspace may indicate that the TCAS operational envelope was not fully compatible with existing air traffic procedures.

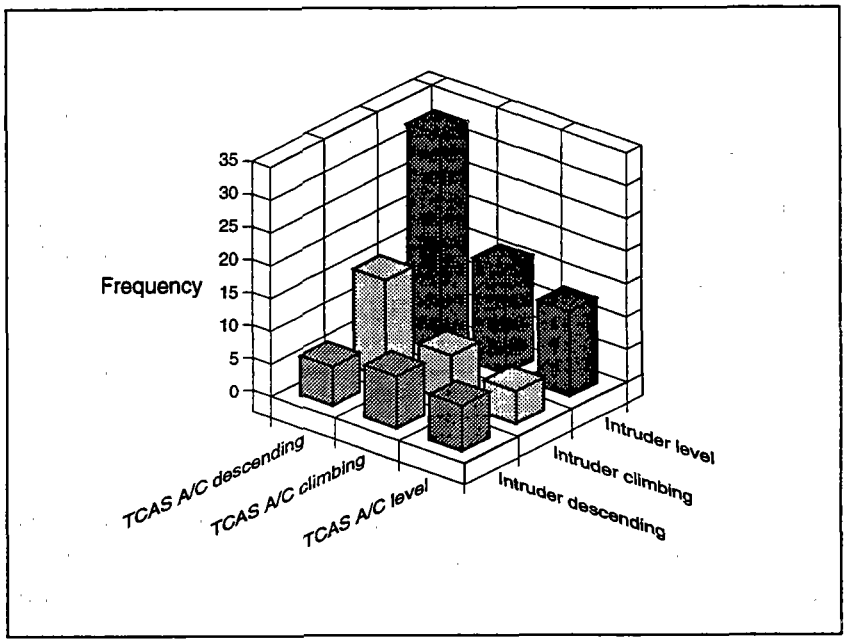
3.3 Patterns of TCAS events

RA encounter profiles

The types of RA encounters between the 'intruder' and TCAS-equipped aircraft are presented in figure 3. A TCAS-equipped aircraft descending to the same altitude as another aircraft maintaining level flight was the most commonly reported scenario (33, or 26% of cases). An example of such an occurrence is where a TCAS-equipped aircraft descended to enter a holding pattern, and a RA was triggered because of a conflict with an aircraft already established in the pattern at a lower level.

FIGURE 3

RA encounter profiles



The next most frequent encounter occurred when the TCAS-equipped aircraft was climbing and the other aircraft was maintaining level flight. In some cases, the TCAS-equipped aircraft would level off to give 1,000-ft separation. However, with the original software, this situation could lead to a RA. Such events typically occurred when one aircraft was departing on a SID or SRD, and the other aircraft was approaching the airfield on a STAR.

EXAMPLE 3

Occurrence number 9302934

23 September 1993 RA 17 km NE Brisbane
B767-300/Cessna 172

At about 2,000 ft altitude and cleared to 1,500 ft, a TCAS TA was received by the B767, indicating another aircraft directly in front and about 900 ft low. The B767 was tracking for a left base for runway 19 at the time and was just east of Mud Island. Descent was stopped and a Cessna high-wing aircraft was sighted. A TCAS RA was then issued but not acted upon because the conflicting aircraft was separated visually. The light aircraft was en route from Maroochydore to Murwillumbah, tracking under the 1,000-ft control area step.

Specific operations

The specific locations and situations which were associated with the most frequent 'triggers' of TCAS-related events were as follows:

Brisbane

TCAS-equipped aircraft:

(i) overflying Archerfield GA aerodrome;

(ii) overflying VFR traffic using the Moreton Bay VFR routes;
(iii) overflying operational maritime transponders in the Brisbane River.

Cairns

TCAS-equipped aircraft:

(i) departure off runway 15 and overflying VFR floatplane/helicopter operations at Cairns Harbour.

Coolangatta

TCAS-equipped aircraft:

(i) overflying VFR traffic using the western and coastal VFR routes.

Melbourne

TCAS-equipped aircraft:

(i) overflying Essendon aerodrome on approach to Tullamarine aerodrome.

Sydney

TCAS-equipped aircraft:

(i) departing from runway 34, maintaining runway heading and assigned climb to 5,000 ft with inbound traffic on the 338 radial assigned to descend to 6,000 ft;
(ii) entering the holding pattern with a high vertical rate of descent;
(iii) overflying VFR route Victor 1;
(iv) overflying the northern lane of entry to Bankstown GA aerodrome;
(v) overflying helicopter operating adjacent to the threshold of runway 25.

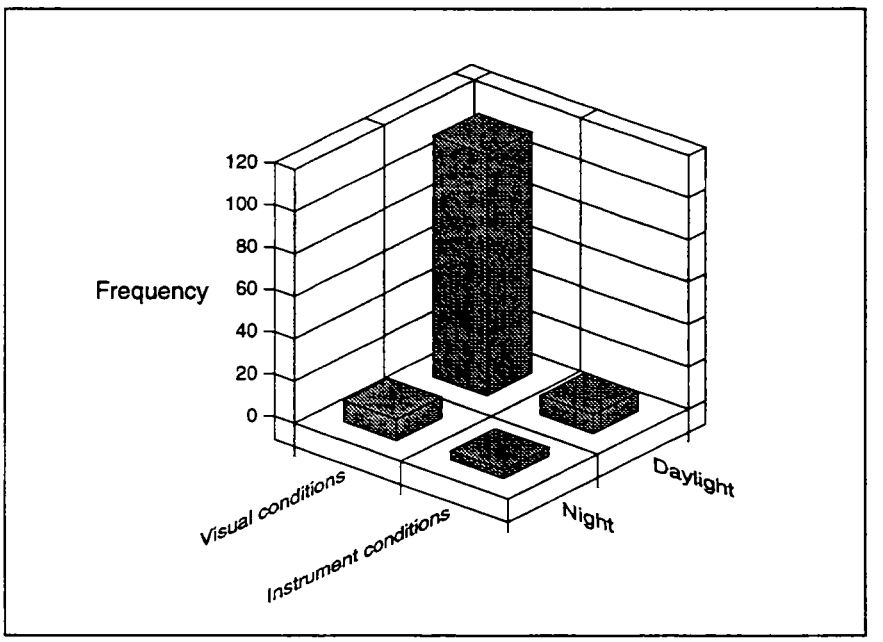
3.4 Visibility issues

Environmental conditions

Figure 4 presents the number of TCAS-related events for each combination of meteorological and light conditions. The majority of events were in good visibility conditions during the day.

FIGURE 4

Meteorological and light conditions

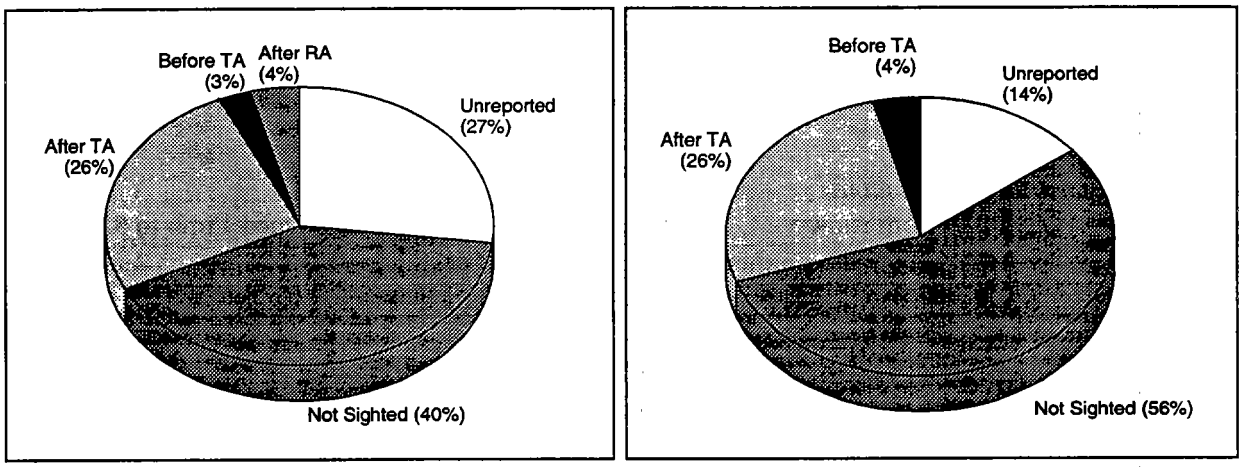


Detection of 'intruder' by flight crew

Although most of the events occurred in VMC, in only 49 (31%) cases did the TCAS-equipped aircraft's flight crew report sighting the conflicting aircraft. For most of these events, the sighting occurred after the TCAS activation. Figure 5 shows when the intruder aircraft was sighted during the TCAS TA and RA activation.

FIGURE 5

Detection of intruder



RA event **TA event**

TCAS provided sufficient information to enable the flight crew to sight the 'intruder' in 26% of the events after the TA occurred. The relatively low level of sighting is understandable given that the majority of TCAS encounters were activated by aircraft from below, with relatively few of the conflicting aircraft being above or at the same level as the TCAS aircraft.

EXAMPLE 4

Occurrence number 9400833

6 April 1994 TA Sydney B767-200/Unreported

Five minutes after departure from runway 07, the pilot reported he had received a TCAS alert on passing 800 ft which indicated an aircraft 100 ft beneath him. The only possible traffic that the tower was aware of was a helicopter holding approximately 0.5 NM north of the runway 25 threshold. ATC were not aware of any traffic on the coast or in Victor 1.

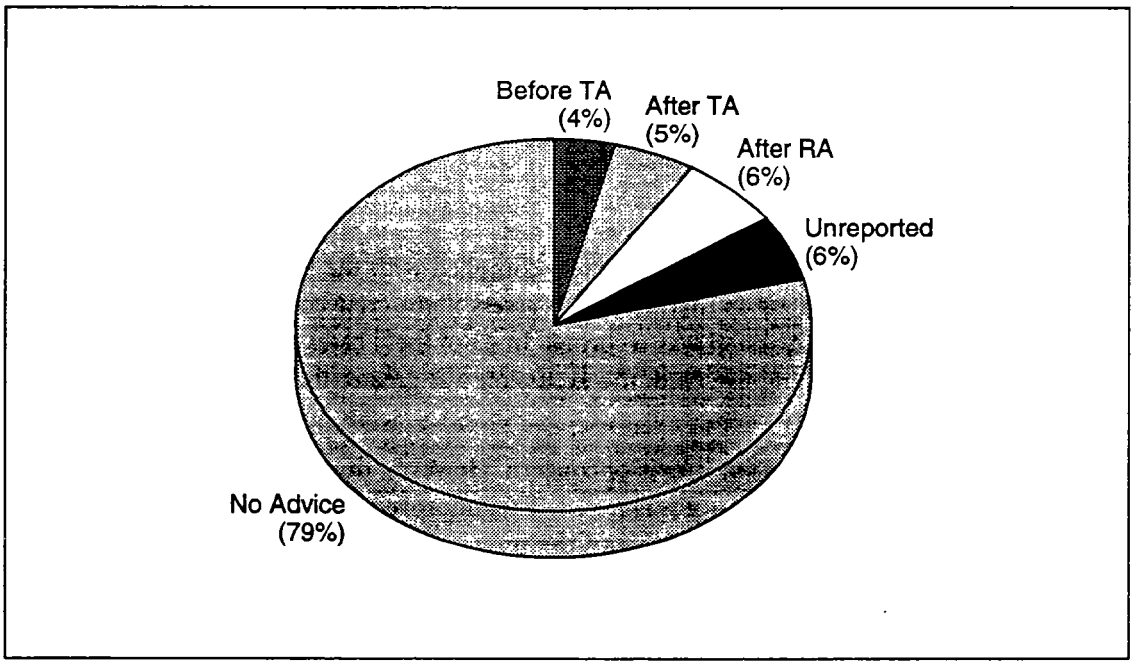
Provision of traffic advice by ATS

Figure 6 shows when Air Traffic Services provided relevant traffic information in the TCAS-related events. Most TCAS events in this study did not involve a breakdown in separation standards. It is not surprising therefore, that 124 (79%) of occurrences were without any traffic information advice from Air Traffic Services. A controller would

normally not provide, or be expected to provide, such advice to aircraft where the prescribed separation standard was planned and/or in place.

FIGURE 6

Traffic information



3.5 Other operational issues

Encounters where both aircraft were TCAS-equipped

There were two reported RA events where both aircraft were equipped with TCAS systems. One of these encounters involved a reversal manoeuvre where an aircraft was initially given a climb instruction to avoid an 'intruder' aircraft. However, as the situation developed, the TCAS software re-assessed the conflict and reversed the instruction.

EXAMPLE 5

Occurrence number 9403910

30 November 1994 RA Sydney B767/B767

The captain's report stated that his aircraft was established in the holding pattern at FL250 when a 'climb' RA was received. That command was followed and after climbing approximately 300 ft, the RA commanded 'descend now'. This command was also followed and on approaching the initial FL250, the command changed to 'monitor vertical speed', followed very quickly by the 'clear of conflict' advisory. The reporter added that this RA event was considered unnecessary as the intruder traffic was known to have been cleared by ATS to descend to FL260 and enter the same holding pattern. The TCAS alert notification form classified the event as a 'nuisance'.

TCAS-induced go-arounds

There were two occurrences where a go-around was conducted following a 'climb' RA event. Both events occurred at Coolangatta in VMC. In each case, the 'intruder' aircraft was a VFR GA aircraft conducting circuit operations under the control of the tower.

For example, a Boeing 767 was on a 1-NM final at 600 ft when the RA occurred and a go-around was initiated. This action required the air traffic controllers to quickly re-assess the situation and provide suitable instructions to the crew of the Boeing 767. The crew was instructed to turn towards high ground to maintain separation from other traffic. Subsequently the Boeing 767 crew reported that they received a warning from their GPWS.

3.6 Flight crew reactions

Flight crew compliance with RA events

Available data indicated that 64% of flight crew complied with the RA while 27% did not. In the remaining cases, data was unavailable to assess flight crew compliance. In 48 cases the extent of the vertical excursion was recorded. In 43 of these cases the excursion was less than 500 ft. In the remaining five cases the excursion was greater than 500 ft but less than 1,000 ft.

The rate of non-compliance with RAs is of concern. However, during the last four months of 1994, a higher rate of compliance was noted. This improvement was most probably due to increased flight crew TCAS exposure and the progressive implementation of the 6.04A logic software, which was intended to reduce unnecessary alerts.

EXAMPLE 6

Occurrence number 9400957

15 April 1994 RA Cairns B767/Helicopter

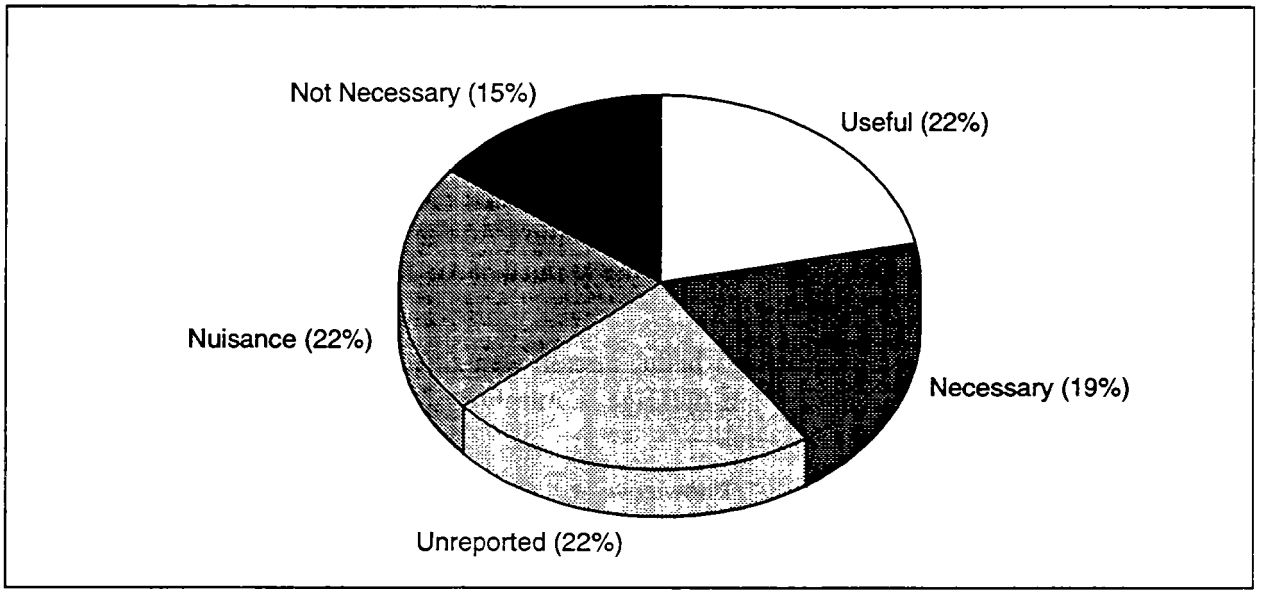
Shortly after becoming airborne, the crew of the B767 received a TCAS resolution advisory due to a helicopter operating near the Cairns wharf. The tower was separating the aircraft visually and the pilots were aware of the other aircraft.

Flight crew assessment of RA events

Those flight crew who had been involved in a TCAS event were asked to rate the usefulness of the RA as 'useful', 'necessary', 'not necessary' or 'nuisance'. Figure 7 presents the ratings provided by the flight crew of the 74 RA events. By combining the 'useful' and 'necessary' events, it can be seen that 41% of the RA events were considered valuable by the flight crew. However, there were a significant number of occasions where the RA was considered to have been unnecessary or a nuisance. Interestingly, many of these latter events were found to have been initiated by the TCAS systems working to specification.

FIGURE 7

Flight crew assessment of RA events



At the beginning of the data collection period, flight crew expressed concerns that TCAS aural warnings in the cockpit may be a distraction and interrupt clear communications with Air Traffic Services. Some pilots were concerned that there would be frequent TAs in terminal areas. There has been no evidence to support either of these concerns. Additionally, since the introduction of 6.04A software, the number of reported TA events has continued to decline. This trend is expected to continue.

3.7 Air traffic controller reactions

Of the 26 TCAS events which occurred in September, October and November 1994, 18 were reported by the relevant air traffic controller. Each of these controllers was interviewed and their responses are outlined below. As these results are based on a small sample of controllers, they must be treated with caution.

Air Traffic Services assessment of TCAS

Thirteen of the controllers interviewed stated initially that the TCAS event was a nuisance at the time of the occurrence because of the unexpected level of disruption to their traffic processing plan.

Their primary concerns were that a controller's planned separation standard may be breached as flight crew responded to a TCAS vertical RA manoeuvre. This concern was not supported by the BASI project data.

After each of the controllers was interviewed, a brief overview of the TCAS system was provided. Each officer was then asked if they wished to reconsider their initial assessment. All but one of the controllers then indicated that TCAS was useful or necessary and that they recognised the potential to benefit the ATS system. However, there were remaining concerns that TCAS could be a source of annoyance in some specific situations.

The progressive installation of revised TCAS software versions and improved controller awareness of TCAS were expected to decrease the number of unexpected TCAS occurrences.

Air Traffic Services TCAS awareness and education

Fourteen of the controllers indicated that they were aware of the existence of TCAS equipment prior to the occurrence. Of concern was that all but three of the controllers interviewed stated that their awareness of TCAS was gained primarily from hearsay and not from the ATS educational material.

While 12 controllers stated that they had received some awareness training on TCAS equipment, none had viewed the CAA (now Airservices Australia) TCAS training video at the time of interview. Those controllers who reported receiving TCAS training indicated that TCAS publications and the Federal Aviation Administration video were the most effective educational material. AICs and the Manual of Air Traffic Services were considered secondary in educational value.

Although information regarding whether aircraft were fitted with TCAS equipment is not transmitted via the flight plan message, a number of controllers thought that this information would be very useful.

Most controllers (13) rated their knowledge of TCAS as only fair, while two considered that they had no knowledge of TCAS, indicating the need for improved TCAS training.

Although the Australian CAA ATS Division provided TCAS education material to ATS officers, the possible implications of TCAS upon the ATS system may not have been evaluated at the workface.

Staff at the CAA School for Air Traffic Services at Launceston had introduced TCAS awareness into the ATC ab initio and conversion courses syllabi late in 1992. However, workface controllers first became aware of TCAS in April 1993 via Aeronautical Information Circular H6/93 and subsequent incorporation, in an abbreviated form, into the *Manual of Air Traffic Services* documentation on 6 January 1994. That document stated the following:

> Controllers must be aware that TCAS equipped aircraft may conduct unexpected deviations from cleared flight paths in response to a TCAS RA. Every assistance should be provided to the flight crew in such circumstances to establish the aircraft back on the cleared flight path or an alternative as dictated by circumstances.
>
> Nuisance RAs can occur in circumstances where an aircraft is climbing or descending to a level 1,000 ft from a conflicting aircraft. Traffic information should therefore be provided on such traffic.

The last sentence of the above paragraph was subsequently replaced on 28 April 1994 to read:

> Recent software upgrades contain changes that will increase the operational compatibility of TCAS and will reduce the frequency of RAs for specific encounters.

The following amendment to the *Manual of Air Traffic Services* issued 18 August 1994, contained more comprehensive information on airborne collision avoidance systems (ACAS), including TCAS and the traffic and collision alert device (TCAD). This amendment contained the following new material which may not have been appreciated by workface controllers:

> It can therefore be taken that International aircraft in Australia, including the Qantas International fleet are TCAS II equipped and
>
> TCAS II reacts to the transponders of other aircraft in the vicinity to determine whether or not there is a potential collision. A warning, based on the time to the closest point of approach (CPA), enables the pilot to identify the conflicting traffic and if necessary, take avoiding action.

A joint industry/CAA TCAS workshop was held in Sydney in April 1994. As a result of that meeting the CAA Quality Assurance Branch improved the education of ATS officers by coordinating the production of an updated TCAS training video. The video and a comprehensive training booklet were released during September 1994.

The change in opinions regarding TCAS discussed earlier is indicative of the need to ensure complete and comprehensive TCAS training is provided and assessed for effectiveness. Air Traffic Services TCAS documentation had not been widely read or understood at the time of this study.

3.8 Other considerations

TCAS can make a positive contribution to improving the system defences in the air traffic system. A sample of occurrences where TCAS may have made such a contribution and reduced the actual or potential risk of mid-air collision is included at appendix 2.

Traffic growth is forecast to increase significantly over the next few years. Consequently, the fitment of TCAS equipment to Australian registered public transport aircraft is likely to become a more critical issue. The Bureau issued IR950117 on 6 June 1995:

Interim Recommendation IR950117

The Bureau of Air Safety Investigation recommends that the Civil Aviation Authority:

(i) mandate the fitment and use of an Airborne collisions Avoidance System (ACAS) in all aircraft engaged in Regular Public Transport (RPT) operations;

(ii) consider the requirement for the fitment and use of a suitable ACAS in other aircraft engaged in the carriage of passengers for hire or reward;

(iii) review the requirements for the carriage and activation of transponders with the objective of maximising the effectiveness of ACAS;

(iv) mandate the standard of ACAS equipment to be carried in each aircraft classification;

(v) set a timetable for the introduction of ACAS equipment; and

(vi) ensure that air traffic services officers are given adequate and timely education and continuation training in the capabilities and operational impact of ACAS equipment.

SUMMARY AND CONCLUSIONS

The information in this report pertains to the operation of TCAS in high-capacity air transport aircraft.

The majority of TCAS events in the study period occurred below 10,000 ft in radar-controlled airspace. Most events occurred in good visibility, and by day.

There was evidence that some pilots and controllers were initially sceptical about the value of TCAS. In the study period, a significant number of RA events were considered by pilots to have been nuisance or unnecessary events. Changes to the TCAS II software logic have significantly reduced the number of TA events and RAs.

TCAS is proving to be a valuable air-safety tool. However, further education, exposure and experience with TCAS is required to ensure that the full value of TCAS is realised.

This study supports the BASI recommendation for the mandating of an airborne collision avoidance system for aircraft engaged in regular public transport operations.

Future ATC systems may not fully overcome problems such as airborne navigation system errors, delays in aircraft communications, human performance limitations and the need for the system to simultaneously monitor conflicting aircraft. Technical advances in ATS systems may incorporate TCAS data into transponder-based radar displays and synthetic displays based on routine aircraft position reports. Consequently, new ATC systems are unlikely to remove the need for TCAS.

If the mandating of ACAS/TCAS technology is to be effective in providing collision avoidance protection to fare-paying passenger aircraft, it is essential that transponders be fitted to aircraft sharing the same airspace.

Appendix 1

TCAS ALERT NOTIFICATION FORM

Bureau of Air Safety Investigation
TCAS ALERT NOTIFICATION FORM
(Please fill in blanks / circle correct answer & Fax to 61-6-247 3117)

Aircraft Operator:

Name: **Telephone:**
(Information requested on this line is optional)
Aircraft Callsign: **Registration:** **Type:**

Aerodrome of Departure: **Destination:**

Date of Event: **Time: (UTC)**
Own Altitude: **ft/FL** **Cleared Altitude: ft/FL**

Own Aircraft Position: **FIR:** **LOC:** **RADIAL:** **DME:**
or
Latitude: **Longitude:**
or
TMA: **SID/STAR Procedure:**

Radar Vectoring: Yes / No
ATC unit: **Frequency:** **SSR Code:**

TA Information (before RA)
TA Issued: Yes / No **Visual contact as a result of TA:** Yes / No

Phase of Flight:
Take-off / Climb / Cruise / Initial Descent / Holding / Approach / Final / Missed Approach

RA Information
Intruder Information: **Bearing:** **o'clock** **Range:** **NM**

Relative Altitude: **ft** above /below Climbing / Level / Descending

Original RA:
Climb / Climb Crossing Climb / Descend / Crossing Descend / Reduce Climb / Monitor Vertical Speed /

If Reduce/Monitor Vertical Speed, Limits: fpm to **fpm**

Subsequent Advisory/Advisories:
Climb Now / Descend Now / Increase Climb / Increase Descent / Monitor Vertical Speed

Did you follow the RA: Yes / No
If appropriate, estimated deviation from Clearance:
RA was: Necessary / Useful / Nuisance

ATC Information: ATC Traffic Information Issued: Yes / No
ATC Avoiding Action Issued: Yes / No
If YES, is it consistent with RA: Yes / No
Flight Conditions: IMC / VMC Day / Night **Visibility:**
Remarks: (if necessary, continue overleaf)

Appendix 2

Breakdown in separation events

Occurrence 9303855

The crew of a DHC8 reported passing a BE1900 at the same level in radar-controlled airspace. The DHC8 was then given immediate descent from FL180 to FL170. There was a SF340 almost immediately below at FL170 which was then given immediate descent to FL160 to increase vertical separation with the DHC8. All three aircraft were conducting scheduled fare-paying passenger operations. There was a breakdown in separation standards and a potential risk of collision None of the three aircraft were equipped with TCAS.

Occurrence 9301823

Both aircraft were conducting scheduled fare-paying passenger operations in reciprocal directions on the same route in radar-controlled airspace. The flight crew of a BAe146 had unknowingly been authorised to descend through the level of an E110. There were mutual sightings by the flight crew of both aircraft and avoiding action taken by the E110. There was a breakdown in separation standards and a potential risk of collision. Neither aircraft was equipped with TCAS.

Occurrence 9302749

A B747, maintaining FL330, requested climb to FL370. The level change was approved. Opposite direction traffic was a B767 at FL350. The time of passing was correctly calculated as 0029, but it was incorrectly notated on the B747's flight progress strip as 0047. At 0029, the flight crew of the B747 advised control that the aircraft was being maintained at FL340 due to opposite direction traffic at FL350. The B747 flight crew were instructed by the controller to return to FL330 and report when maintaining. The B747 flight crew reported their return to FL330 at 0030 and sighting the B767 as it passed 1,500 ft directly overhead. Both aircraft were conducting international scheduled fare-paying passenger operations. There was a breakdown in separation standards and a potential risk of collision. Neither aircraft was equipped with TCAS.

Occurrence 9303952

An inbound PA31 had been assigned a descent to 3,000 ft by the approach controller. At approximately the same time, an international MD11 aircraft had just departed and been instructed by the departures controller to turn left towards the PA31 and to climb to 3,000 ft. Subsequently, the MD11 turned in front of the PA31 and the required lateral separation was lost when both aircraft were at about the same altitude. Both aircraft were conducting scheduled fare-paying passenger operations. There was a breakdown in separation standards and a potential risk of collision. Neither aircraft was equipped with TCAS.

Occurrence 9401006

A B767 had been cleared for final approach to runway 34. When the aircraft was at about 5 NM, the pilot advised the tower of a TCAS RA and that he was commencing a missed approach. The aircraft was then processed for a landing on runway 25. After landing, the flight crew advised that they had received warnings on two conflicts. The only possible traffic of which ATS were aware could have caused the alert was a helicopter at 500 ft in Victor 1, which passed under the B767 at approximately the time of the alert. Subsequent radar analysis indicated that the helicopter had violated the control zone boundary and climbed to approximately 800 ft immediately below the B767. There was a potential risk of collision. The B767 aircraft was equipped with TCAS.

Occurrence 9401282

The flight crew of a B737 reported a TCAS TA whilst descending to FL180 at Bindook. The only known traffic was a FK50 cruising at FL170. The flight crew were uncertain if the TCAS display was indicating the FK50 as being 700 ft or

1,000 ft below. The ATS radar symbols were superimposed and it was not possible for the controller to determine the actual aircraft vertical separation at the time. Subsequent radar analysis confirmed a vertical separation of only 700 ft had existed and that there was a breakdown in separation standards. There was a potential risk of collision. The B737 was the only aircraft equipped with TCAS.