Australian Government

Australian Transport Safety Bureau

AVIATION SAFETY INVESTIGATION REPORT
200203449

Flying training accident at Moorabbin

Cessna 172R, VH-CNW
Cessna 172R, VH-EUH
29 July 2002

When the ATSB makes recommendations as a result of its investigations or research, safety (in accordance with its charter) is its primary consideration. However, the Bureau fully recognises that the implementation of recommendations arising from its investigations will in some cases incur a cost to the industry.

Readers should note that the information in ATSB reports is provided to promote safety: in no case is it intended to imply blame or liability.

Cover photo: Cessna Aircraft Company

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This report was produced by the Australian Transport Safety Bureau (ATSB), PO Box 967, Civic Square ACT 2608.

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INTRODUCTION

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory or other external influence.

The objective of the ATSB is safe transport. To achieve this objective the ATSB carries out investigations and safety studies to identify possible safety issues, and then recommends safety actions aimed at addressing those issues.

In terms of aviation, the ATSB is responsible for investigating accidents, serious incidents, incidents and safety deficiencies involving civil aircraft operations in Australia, as well as participating in overseas investigations of accidents and serious incidents involving Australian registered aircraft. The ATSB also conducts safety studies of the underlying factors and trends within the aviation system that have the potential to affect safety. A primary concern is the safety of commercial air transport, with particular regard to fare-paying passenger operations.

The ATSB performs its aviation functions in accordance with the provisions of the *Air Navigation Act 1920*, Part 2A[1]. Section 19CA of the Act states that the object of an investigation is to determine the circumstances surrounding any accident, serious incident, incident or safety deficiency to prevent the occurrence of similar events. The results of these determinations form the basis for safety advisory notices and recommendations, and ultimately accident prevention programs. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations.

Under the *Air Navigation Act* it is not the object of an investigation to determine blame or liability. However, it should be recognised that an investigation report must include factual material of sufficient weight to support the analysis and conclusions reached. That material will at times contain information reflecting on the performance of individuals and organisations, and how their actions may have contributed to the outcomes of the matter under investigation. At all times the ATSB endeavours to balance the use of material that could imply adverse comment, with the need to properly explain what happened, and why, in a fair and unbiased manner.

ATSB investigations are multi–disciplinary. Investigators are drawn from a range of professional backgrounds including pilots, air traffic controllers, human factors professionals[2], Licensed Aircraft Maintenance Engineers (LAMEs), professional engineers, and cabin safety and technical analysis specialists.

The ATSB does not adhere only to one ‘investigation model’, but applies the best methods and techniques appropriate to each situation.

The ATSB employs a broadly systemic approach that aims to identify not only what happened, but why it happened. That approach can reveal both immediate and underlying safety issues. A key principle is that human error, though undesirable, is nevertheless both prevalent and pervasive. Hence, recommended safety action is typically aimed at limiting and mitigating the effect of human error.

[1] In July 2003, the *Air Navigation Act 1920*, Part 2A was replaced with the *Transport Safety Investigation Act 2003*. However, this investigation was commenced and conducted under Part 2A of the *Air Navigation Act 1920*.

[2] Human factors is the multi-disciplinary science that applies knowledge about the capabilities and limitations of human performance to all aspects of the design, operation, and maintenance of products and systems. It considers the effects of physical, psychological, and environmental factors on human performance in different task environments, including the role of human operators in complex systems.

ATSB investigations include analysis of any relevant human factors or organisational issues. Consideration of these aspects does not, however, in any way diminish the importance and priority given to operational, mechanical, and technical issues. The different aspects are, in fact, very much complementary.

EXECUTIVE SUMMARY

At approximately 1840 Eastern Standard Time on Monday 29 July 2002, two Cessna Aircraft Company 172Rs, registered VH-CNW and VH-EUH, collided while on short final approach to runway 17 left (17L) at Moorabbin airport, Victoria. The two aircraft became entangled, with CNW on top of EUH. The entangled aircraft impacted the runway and came to rest after sliding a short distance along the runway surface.

The instructor and student pilot of EUH were conducting night circuit training and the pilot of CNW, the sole occupant, was conducting night circuits. Both aircraft were using runway 17L. The instructor and student pilot of EUH were able to exit their aircraft before fire engulfed both aircraft. The pilot of CNW was fatally injured.

Both aircraft were based at Moorabbin airport. The Moorabbin Air Traffic Control Tower was not in operation at the time of the accident and mandatory broadcast zone (MBZ) procedures were in use, under which pilots are required to:

- See and avoid other aircraft,
- Carry a serviceable radio, and
- Make mandatory radio broadcasts when commencing to taxi for take off, when entering a runway for take off, prior to entering an MBZ when inbound or transiting and when inbound and joining the circuit.

Six aircraft were operating in the MBZ at the time of the accident. All were being flown by pilots who held a commercial pilot licence or some higher qualification.

The mandatory broadcast procedures in an MBZ provide a basic alert to assist pilots to see and avoid other aircraft, and can be supplemented by additional discretionary broadcasts. A mandatory broadcast may contain insufficient information to enable pilots to see-and-avoid other aircraft, or to enable them to make a meaningful assessment of the location of other aircraft. The pilots of CNW and EUH made all the relevant mandatory broadcasts. They also made a discretionary broadcast at about the time they were established on the base leg of the circuit. Those broadcasts did not effectively alert either pilot to the collision potential with the other aircraft.

Even though the two aircraft were of the same type and were operating at similar speeds in the circuit, radar data indicated that the pilots of EUH conducted a wider circuit than the pilot of CNW. The EUH circuit would have taken approximately 7 minutes to complete, whereas the pilot of CNW conducted a circuit that would have taken approximately 4.5 minutes to complete. Both circuit dimensions were within the range of circuit dimensions that were being conducted by other pilots at the time, and were not considered by the investigation to be contrary to procedures. While the dimensions of the circuits flown by the two accident aircraft were not unusual, the different circuit dimensions, and the consequent difference in the elapsed time, removed the natural spacing that would have typically resulted from the difference in take-off times. In the absence of any other defence or action, the different circuit dimensions led to the two aircraft converging on the final approach leg of the circuit. Neither of the pilots involved in the accident was aware of the impending collision.

The investigation identified the following significant factors:

- The different circuit dimensions negated the natural spacing provided by the difference in take-off times, even though both EUH and CNW were the same aircraft type and were operating in the circuit at similar speeds.

- None of the pilots involved in the accident saw the other accident aircraft in sufficient time to enable either of them to avoid the collision.

- The broadcasts made by the pilots did not assist their situational awareness.

Additionally, the investigation found deficiencies in the risk management process associated with the reduction in the Moorabbin airport air traffic control tower hours of operation. It could not be determined whether the reduction in tower hours contributed to the accident.

An earlier report[3] found that human performance limitations in the visual scanning '…process can reduce the chance that a threat [potentially conflicting] aircraft will be seen and successfully evaded. These human factors are not "errors" nor are they signs of "poor airmanship". They are limitations of the human visual and information processing system which are present to various degrees in all pilots'.

In particular, the practice of routinely re-analysing the information on which decisions are made, especially in airspace where the potential for a traffic confliction is relatively high, might help compensate for those inherent human performance limitations of the human visual and information processing system.

While not required under MBZ procedures, prior to the accident, the flying school required its instructors and student pilots to make a base broadcast at the start of the base leg of the circuit. Subsequent to the accident, the flying school has amended the content of that broadcast. Instructors and student pilots are now required to append their perceived number in the landing sequence to the base broadcast.

In September 2002, Airservices Australia approved a plan for an ongoing airport movement review outside tower hours for ATC towers that were not open 24 hours per day, which included Moorabbin tower, to monitor the need for an air traffic control service.

The Australian Transport Safety Bureau will be publishing a discussion paper in the next few weeks entitled '*Review of mid-air collisions involving general aviation aircraft in Australia between 1961 and 2002'*.

[3] The Bureau of Air Safety Investigation (BASI) became part of the newly formed Australian Transport Safety Bureau (ATSB) on 1 July 1999. The BASI report made six recommendations including '… The CAA should take into account the limitations of see-and-avoid when planning and managing airspace and should ensure that unalerted see-and-avoid is never the sole means of separation for aircraft providing scheduled services'. In 2001, the ATSB classified the CASA response to that recommendation as CLOSED – ACCEPTED on the basis that CASA agreed that the limitations of see-and-avoid should be taken into account when planning and managing airspace and the Authority had indicated that appropriate risk management techniques will be used to establish airspace regulatory safety requirements. The ATSB agreed that the use of the absolute 'never' was overtaken by risk assessment.

1 FACTUAL INFORMATION

1.1 History of the flights

On 29 July 2002, at approximately 1834 Eastern Standard Time (EST), a Cessna Aircraft Company 172R (C172), registered VH-EUH, became airborne at Moorabbin airport to conduct night circuit training under the visual flight rules (night VFR) using runway 17 left (17L). On board was a student pilot who was conducting night VFR circuit training for the first time, and an instructor. The student pilot was seated in the left control seat, and the instructor was seated in the right control seat. Immediately before the accident, six aircraft were operating in the Moorabbin circuit pattern. Five of those aircraft were conducting circuit operations and one had joined the circuit having arrived from the southwest with the intention of landing. Another aircraft had just landed and had vacated the runway.

At approximately 1837 EST, another C172, registered VH-CNW, also became airborne at Moorabbin airport to conduct circuits under the night VFR using runway 17L. On board was a pilot who was conducting circuits to accumulate night flying hours as pilot-in-command and was seated in the left control seat. Both aircraft were owned and operated by the same flying training school. A number of other pilots were conducting circuit operations under the night VFR, along with the two accident aircraft. Figure 1 shows a normal left circuit pattern similar to the circuit pattern flown by the pilots of the two accident aircraft, along with the designated legs of a circuit pattern. During radio communications, pilots use their location in relation to these legs to describe an aircraft's location in the circuit pattern. For example, a pilot on the base leg may broadcast 'Charlie November Whisky, base'.

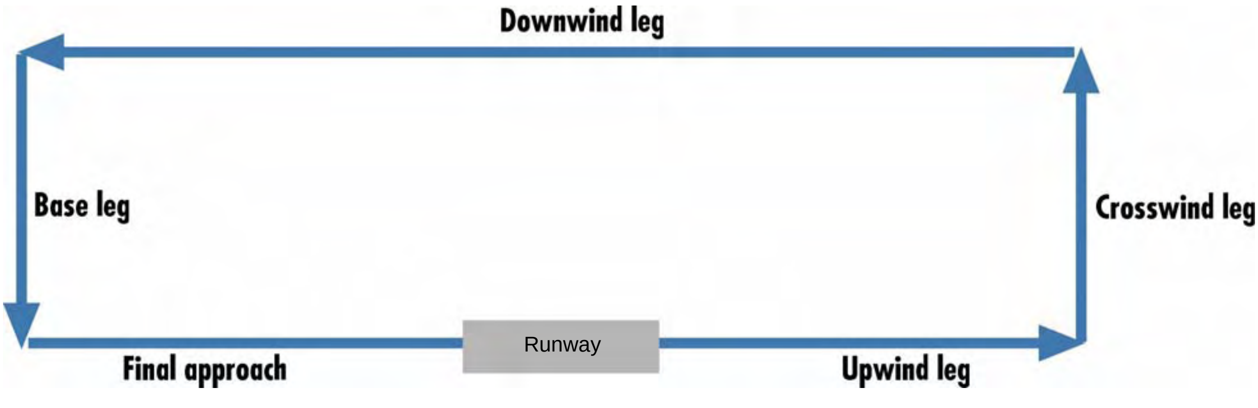

Figure 1**:** Legs of a normal circuit pattern

The airspace surrounding Moorabbin airport operated under General Aviation Aerodrome Procedures (GAAP)[4] between the hours of 0800 to 1800. The GAAP control zone (CTR) had been deactivated at the scheduled time of 1800 EST. At the time of the accident all aircraft operating in the circuit were operating under mandatory broadcast zone (MBZ) procedures[5].

Radar data indicated that the pilots of EUH conducted a wider circuit than the pilot of CNW. The EUH circuit would have taken approximately 7 minutes to complete, whereas the pilot of CNW conducted a circuit that would have taken approximately 4.5 minutes to complete. Both circuit dimensions were within the range of circuit dimensions that were being conducted by other pilots at the time. Figure 2 shows the circuit patterns of the two accident aircraft, and the circuit patterns of the other aircraft that were operating in the circuit at the time of the accident.

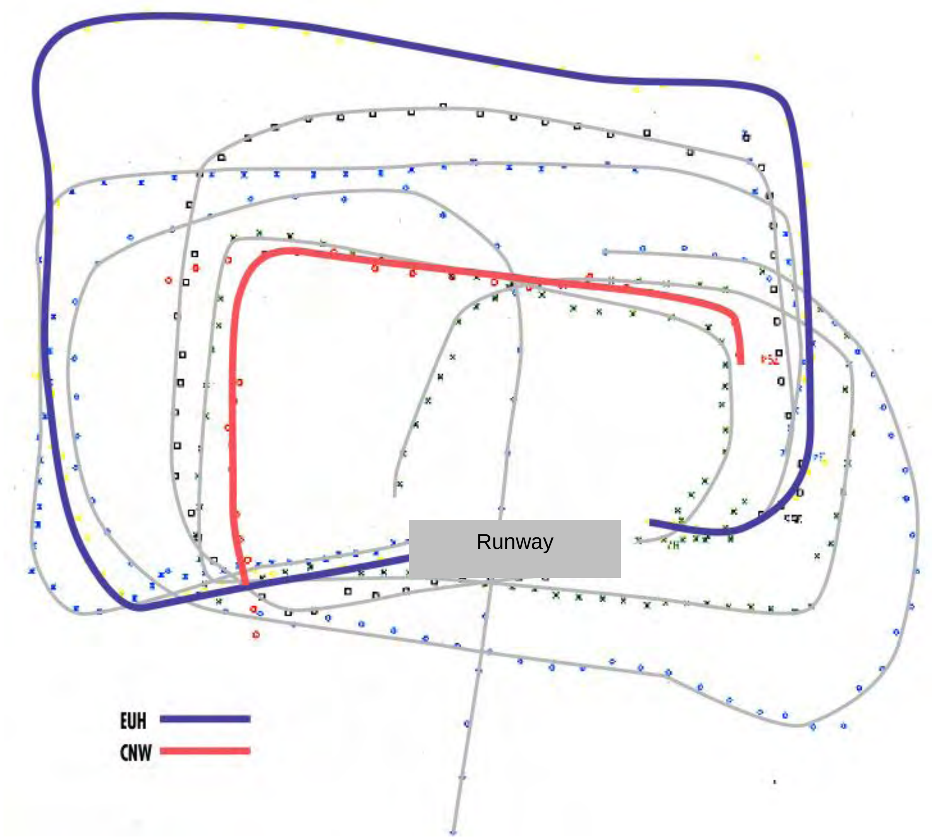

Figure 2: Radar plot of aircraft in the Moorabbin circuit between 1830 and 1845 on 29 July 2002 (the radar tracks of some aircraft not considered significant to the sequence of events are not depicted).

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[4] The AIP advised pilots that at a GAAP CTR in visual meteorological conditions 'the pilot in command is primarily responsible for separation from other aircraft. ATC controls runway operations with landing and take-off clearances and facilitates a high movement rate by providing traffic information and/or sequence instructions.'

[5] MBZ procedures are discussed in section 1.17.1.

The instructor and student pilot on board EUH reported that they conducted their circuit at the prescribed height of 1,000 ft above ground level. There was no indication that the pilot of CNW conducted operations at other than the prescribed circuit height.

EUH was approximately on mid-base leg as CNW completed the turn from the crosswind leg onto the downwind leg of the circuit. At that time, EUH was about 2.5 NM ahead of CNW, and moving right to left in relation to CNW as EUH descended on base leg. The instructor and student pilot on board EUH reported that they saw an aircraft, which they believed to be CNW, in a location that was subsequently found by the investigation to be CNW's location at that time. Those relative locations are shown in figure 3.

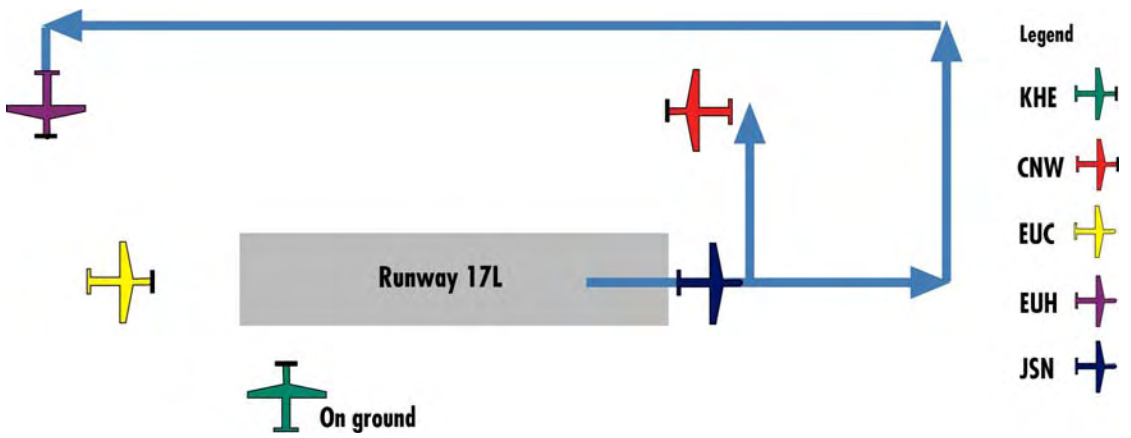

Figure 3:

Depiction of aircraft locations as CNW turned onto downwind leg.

Figure 4 shows the traffic situation approximately 60 seconds later. The pilots of EUH were about to turn onto final approach as CNW turned onto base leg. At the same time another aircraft, VH-EUC, was on final approach, close to touching down for a touch-and-go landing, abeam and to the left of CNW.

Other pilots operating in the MBZ heard the pilot of CNW make a base broadcast. The actual location of CNW at the time the pilot made that base broadcast could not be determined. However, the flying school from which the students and instructor came advocated that the base broadcast should be made once the aircraft is established on the base leg of the circuit.

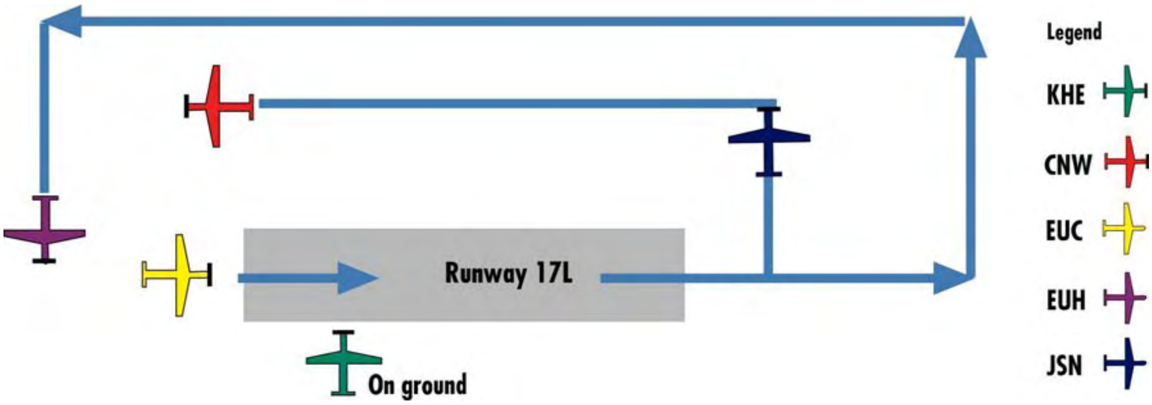

Figure 4

Depiction of aircraft locations before CNW turned onto base leg.

The pilot of CNW commenced the turn onto the final approach approximately 50 seconds later. At about that time EUC was airborne and on the upwind leg following the touch-and-go landing, and another Cessna 172, VH-KHE, was on the runway and had commenced a take-off roll. Those locations are shown in figure 5.

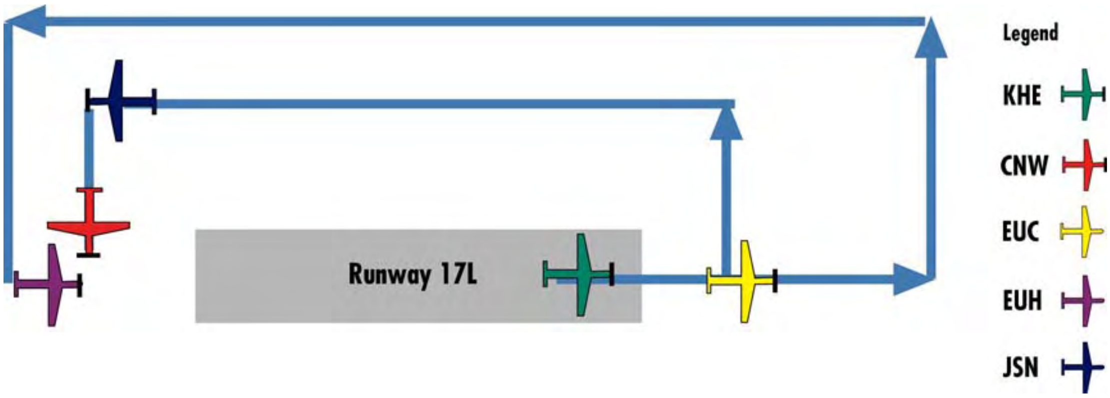

Figure 5: Depiction of aircraft locations before CNW turned onto final approach.

A number of witnesses then saw two aircraft on final for runway 17L, one above the other, in close proximity and converging.

The pilot of a Cessna Aircraft Company 152 (C152), registered VH-JSN, who was on the base leg when the two accident aircraft were on final approach, saw EUH and CNW on final, and made a general broadcast stating that two aircraft were on final. The pilot of CNW then broadcast a position report when on late final in response to that broadcast. Witnesses reported that there was nothing in the tone or content of that broadcast to indicate that the pilot of CNW was aware of the proximity of EUH. There was no other indication that the pilots of either aircraft were aware of the proximity of the other aircraft.

Almost immediately after that broadcast from the pilot of CNW, the two aircraft collided while they were still in the air but close to the ground. They became entangled, with CNW on top of EUH. The aircraft then impacted the runway, still entangled, with EUH in a right wing-low attitude. The right main landing gear of EUH failed during the impact, and the aircraft slid together to a stop some 60 metres further along the runway. Both aircraft had 30 degrees flap extended at the time of the accident.

A fire commenced before the aircraft had stopped moving. Shortly after the aircraft stopped, the fire increased in intensity to engulf and consume both aircraft. The occupants of EUH escaped from their aircraft. The pilot of CNW sustained fatal injuries.

1.2 Injuries to persons

EUH

Injuries	Pilots	Passengers	Others	Total
Fatal				
Serious				
Minor	1			1
None	1			1

CNW

Injuries	Pilot	Passengers	Others	Total
Fatal	1			1
Serious				
Minor				
None				

1.3 Damage to aircraft

Both CNW and EUH were destroyed by the impact forces and subsequent fire (see section 1.12).

1.4 Other damage

There were gouges and scrape marks on the runway surface. The gouges were sufficient to require repairs to be carried out to the surface of the runway before the runway was available for use following the collision.

1.5 Personnel information

VH-CNW (student pilot particulars)	
Type of licence	Commercial Pilot (Aeroplane) Licence
Medical certificate	Class 1 current and valid to 10/12/2002

Flying experience (total hours)	236.3
Hours on the type	8.8
Hours flown in the last 24 hours	0.8
Hours flown in the last 7 days	6.0
Hours flown in the last 90 days	6.0

The pilot of CNW commenced flight training at Bankstown Airport in September 1999 and had held a Commercial Pilot (Aeroplane) Licence, since December 2001.

The pilot of CNW had conducted three training flights in the 3 days leading up to the accident, totalling 5 hours. On the morning of the day of the accident, the pilot had successfully completed a systems examination towards an Air Transport Pilot (Aeroplane) Licence, for which she had studied long periods in the previous days. That was followed by a 48 minute solo aerobatic flight. The pilot of CNW was reported to have retired to bed sometime after 0030 on the night before the accident and was awake by 0700.

Although the pilot of CNW had reported to a colleague of feeling fatigued before the accident flight, there were no other indications of any personal, physiological or medical issues that may have influenced the pilot's performance.

VH-EUH (student pilot particulars)

Type of licence	Commercial Pilot (Aeroplane) Licence
Medical certificate	Class 1 current and valid to 11/02/2003
Flying experience (total hours)	178.2
Hours on the type	2.5
Hours flown in the last 24 hours	1.2
Hours flown in the last 7 days	2.8
Hours flown in the last 90 days	10.1

The student pilot commenced flight training at Bankstown Airport in October 2000 and had held a Commercial Pilot (Aeroplane) Licence, since July 2001. He was conducting his first night VFR circuit training flight as a student pilot with an instructor at the time of the accident.

The student pilot of EUH had conducted three training flights in the 3 days leading up to the accident, totalling 2 hours and 54 minutes, and had conducted a 60 minute solo aerobatic flight on the day of the accident. The student pilot had studied during the day of the accident flight. He reported that he retired to bed at around 2300 on the night before the accident and was awake by 0900.

There were no indications of any personal, physiological or medical issues that may have influenced the pilot's performance.

VH-EUH (Instructor particulars)

Type of licence	Commercial Pilot (Aeroplane) Licence
Medical certificate	Class 1 current and valid to 09/11/2003
Flying experience (total hours)	1010.5

Hours on the type	700
Hours flown in the last 24 hours	7.2
Hours flown in the last 7 days	13.1
Hours flown in the last 90 days	139.0

The instructor held a Commercial Pilot Licence - Aeroplane, a grade two instructor rating and had logged approximately 550 hours as an instructor.

The instructor had conducted two navigation flights on the day of the accident totalling 6 hours and 36 minutes. The last navigation flight arrived back at Moorabbin at 1757. After returning from that flight, due to the commitments of other instructors, he was then tasked to instruct on night circuit operations. The instructor reported that he retired to bed at around 2030 on the night before the accident and was awake by 0730.

There were no indications of any personal, physiological or medical issues that may have influenced the instructor's performance.

1.6 Aircraft information

VH-EUH	
Manufacturer	Cessna Aircraft Company
Model	172 R
Serial number	17280362
Registration	VH-EUH
Year of manufacture	1998
Certificate of airworthiness	MB/10317/01
Issue Date	06/08/98
Certificate of registration	MB/10317/01
Issue Date	31/07/98
Maintenance release	Valid to (date/hours) 10/7/2003 or 2450 hours total time in service

The weight and centre of gravity of EUH were within the limits for the flight. The aircraft had a current certificate of airworthiness and a valid maintenance release. No maintenance work was outstanding at the time of the accident. The pilots of EUH reported that the aircraft was operating normally at the time of the accident.

VH-CNW	
Manufacturer	Cessna Aircraft Company
Model	172 R
Serial number	17280922
Registration	VH-CNW
Year of manufacture	2000
Certificate of airworthiness	JT/10945/01
Issue date	19/01/01
Certificate of registration	JT/10945/01
Issue date	02/08/00
Maintenance release	Valid to (date/hours) 19/7/2003 or 1104.8 hours total time in service

The pilot of CNW broadcast on short final approach seconds prior to the accident. According to witness reports, there was no indication in that broadcast that CNW was not operating normally at that time. There were no other broadcasts made by the pilot of CNW that indicated that the aircraft was operating other than normally during the circuit leading up to the accident.

The weight and centre of gravity of CNW were within the limits for the flight. The aircraft had a current certificate of airworthiness and a valid maintenance release. No maintenance work was outstanding at the time of the accident. Examination of the aircraft engine revealed no anomalies that could be associated with a pre-impact condition.

1.7 Meteorological information

The weather was reported as fine and clear with a light south-westerly wind. The weather was not considered to be a factor in this occurrence.

1.8 Aids to Navigation

The pilots of CNW and EUH were conducting circuit training under the night VFR. Circuit operations under the night VFR require a pilot to navigate by visual reference to ground features, and to orientate the circuit in relation to the landing runway. There was no indication that the pilots of either aircraft were navigating in the circuit area by any other means. The instructor in EUH reported that gliding distance to the runway in the event of an engine failure had been taken into consideration when determining the dimension of the circuit.

1.9 Communications

Pilots operating in the Moorabbin MBZ were required to communicate on the designated Moorabbin MBZ frequency of 118.1 megahertz (MHz). Prior to taxiing for take-off, pilots of aircraft would normally listen to the weather information on the automatic terminal information service frequency of 120.9 MHz before monitoring the MBZ frequency.

During the hours of activation of the Moorabbin control tower, Airservices Australia (Airservices) recorded all voice transmissions made on air traffic service radio frequencies. Those recorders were selected off during MBZ hours as there was no requirement for Airservices to record voice transmissions during periods of MBZ operation. Therefore, there were no Airservices voice recordings of any transmissions made by pilots operating in the Moorabbin MBZ. No other recordings of voice transmissions were found.

1.10 Aerodrome information

Moorabbin airport is surrounded by urban development. There is extensive domestic and industrial lighting on the ground within and around the area encompassed by aircraft conducting circuits operations.

The pilots of all aircraft in the circuit were conducting left circuits using runway 17L, the preferred runway in the prevailing weather conditions. Runway 17L was 1335 m in length and was equipped with operational medium intensity runway lighting.

1.11 Recorded Information

1.11.1 Flight recorders

Neither aircraft was fitted with a flight data recorder or a cockpit voice recorder, nor were they required by the relevant aviation regulations.

1.11.2 Radar recording

The investigation reviewed the data from the Melbourne terminal primary radar. Within the greater Melbourne area, the terminal radar network was primarily intended to be used by air traffic control to provide an air traffic service to aircraft operating into and from controlled airspace and to provide traffic information to other aircraft in accordance with the Aeronautical Information Publication (AIP). The radar that provided the track data for the investigation was located approximately 41 km northwest of Moorabbin airport.

The Moorabbin circuit area was within the range of the Melbourne terminal primary radar. The air traffic services radar network that covered the greater Melbourne area consisted of both primary radar and secondary surveillance radar (SSR) coverage. Primary radar processed reflected radar signals from aircraft, and SSR processed signals transmitted from a transponder located on board many aircraft. Aircraft transponders can be encoded to provide air traffic controllers with aircraft identification and altitude information.

It was the normal procedure for pilots of VFR aircraft that were confining their operations to the Moorabbin MBZ circuit area not to activate their transponders. Consequently, most of the recorded radar data relevant to the Moorabbin MBZ only provided a primary radar indication of the aircraft location and therefore provided no aircraft identification or aircraft altitude information. Furthermore, radar tracks of aircraft operating in the Moorabbin MBZ were not visible when the aircraft approached ground level, because of the limitations of the area of radar coverage. In general, aircraft were only reliably detected by the primary radar when they were above approximately 300 ft above ground level.

The locations of aircraft that had entered the Moorabbin MBZ circuit area from elsewhere were identified from their SSR codes. The pilots of those aircraft had activated their aircraft transponders. The investigation was able to establish the primary radar tracks for aircraft operating in the Moorabbin circuit at the time of the accident by correlating pilot recollections of their locations at the time of the accident with the recorded primary radar tracks.

In accordance with the AIP[6], pilots operating within the Moorabbin MBZ were required to activate their aircraft's radar transponder. Both CNW and EUH were equipped with transponders that would, if serviceable and activated, enable the radar to record, among other information, the location and altitude of the transponding aircraft. However, neither the pilot of CNW nor the pilots of EUH were operating their aircraft's transponders while conducting circuit operations during the circuit leading up to the accident. The fact that the pilots of EUH and CNW had not activated their aircraft's transponder did not contribute to the circumstances of the accident, but meant that the investigation could not accurately determine the altitude of either accident aircraft during the circuit leading up to the accident.

1.12 Wreckage and impact information

There was some debris along the undershoot area of runway 17L before the point where the aircraft impacted the runway.

Ground marks and wreckage after the initial impact point on the runway confirmed that the aircraft hit the ground with the lower aircraft, EUH, banked to the right. The wheel rim of the right main landing gear failed at the initial impact point, and the right main landing gear leg also failed as the two aircraft slid along the runway. The right wing strut separated from EUH during the ground slide, and the right wing separated from the fuselage at the leading edge before the aircraft came to rest. The left main landing gear of the upper aircraft, CNW, was observed by the instructor pilot to penetrate the rear window of EUH. The impact damage was consistent with that observation.

EUH came to rest with its fuselage pointing approximately 30 degrees to the right of the runway 17L centreline, and CNW came to rest on top of EUH, with its fuselage pointing approximately 90 degrees to the right of the runway 17L centreline.

1.13 Medical and pathological information

[6] The Airservices Australia *Aeronautical Information Publication* (AIP) ENR 8 details the requirements for the operation of aircraft transponders. The AIP was an Australian operational document used by pilots. The AIP contained the rules of the air and air traffic control procedures related to relevant Civil Aviation Regulations, Civil Aviation Orders, Air Services Regulations and Air Navigation Regulations.

All pilots had current and valid medical certificates for the operation being undertaken at the time of the accident. There was no evidence that any medical condition affected the performance of any of the pilots before the accident.

Post mortem results showed that the pilot of CNW died from the effects of fire following the impact, and that the pilot suffered no injuries other than those produced by fire. Toxicological testing found no abnormalities other than those associated with the post-impact fire, and no evidence of the presence of any drugs, including alcohol were recorded.

1.14 Fire

Both aircraft were consumed in the post-impact fire. Witnesses on the ground reported that the fire started before the aircraft had stopped sliding on the runway and witnesses in other aircraft indicated that the fire continued for some time.

There is no airport rescue and fire fighting service at Moorabbin airport, nor do the regulations require there to be. The Metropolitan Fire Brigade received a number of emergency calls relating to the accident, and later reported that they commenced fighting the fire 7 minutes and 46 seconds after receiving the alert message. The brigade stated that both aircraft had been heavily damaged by fire by the time they arrived on the scene.

1.15 Survival aspects

The pilots of EUH survived the mid-air collision and the subsequent impact with the ground.

The post mortem report indicated that the pilot of CNW survived the mid-air collision and the subsequent impact with the ground but was unable to evacuate the aircraft before it was consumed by the post-impact fire.

1.16 Organisational and management information

1.16.1 The aircraft operator

Both CNW and EUH were operated by the same flying training school. That school had developed a comprehensive flying training syllabus that was implemented under the supervision of qualified flying instructors. Consistent with normal practices, where the flying training school considered appropriate, students were required to reach a particular level of competency before being deemed capable of progressing onto another component of the syllabus. In these circumstances, students were assessed by the management team, including the Chief Flying Instructor and senior line instructors, before being allowed to progress to the next component of the syllabus.

The flying training syllabus conformed to Civil Aviation Safety Authority (CASA) requirements and was annexed to the flying school’s operations manual. Safety was monitored through management supervision of qualified line instructors who coordinated the activity of the students. On the night of the accident, the chief pilot made weather observations and ensured that aircraft were serviceable. Students also received pre-flight briefings.

It was reported that instructors and management continuously assessed weather conditions, traffic density and complexity, and serviceability of aircraft as students were conducting flying operations. An evaluation of student ability was made against these factors to ensure that the perceived level of competency of each student was appropriate in the prevailing conditions. The Chief Pilot reported that line instructors had, in the past, exercised their authority to require a student to land if, in the opinion of the instructor, the conditions were beyond the capability of a particular student.

1.16.2 Airspace management

During the hours specified in AIP En Route Supplement Australia (ERSA), Moorabbin was a controlled airport operating under General Aviation Aerodrome Procedures (GAAP). On 21 December 1998, the number of controllers employed in the Moorabbin air traffic control tower reduced from ten to seven, and the tower operating hours were reduced from 12 hours on weekdays and 11 hours on weekends, to 10 hours daily. Prior to that date, pilots operating in the airspace between 1800 and 2000 hours Eastern Standard Time (EST) on a Monday (the weekday the accident occurred) were provided with a GAAP air traffic control service[7]. After 21 December 1998 MBZ procedures applied between those hours.

To facilitate the changes of 21 December 1998, Airservices undertook a review of its air traffic services operations at Moorabbin airport to ‘improve efficiencies and thus provide an affordable service to its customers’. Airservices engaged a consultant to produce a risk assessment report as a part of the change management process for the reduction in the number of controllers employed at Moorabbin and the consequent reduction of tower hours of operation. Airservices also produced an internal Safety Case and a Safety Case Review based on the risk assessment report. The risk assessment report identified four perceived hazard scenarios and allocated a level of risk to each. Airservices also produced a safety case that documented the risk management process that was to be employed in addressing the identified hazard scenarios to ensure that ‘reduced hours of cover will not compromise air safety in the [Moorabbin] MBZ environment’. The major objective of both the risk assessment report and the subsequent safety case was to ensure that there was ‘no step increase (or no increase in the identified level of risk) posed by the new ATC staffing levels and hours of operation proposed for Moorabbin airport’.

The standards for the regulatory oversight of Airservices by CASA are stated in the April 1996 publication, *Final Draft Regulatory Arrangements and Standards for the Safety Regulation of Airservices and Aerodrome Rescue and Fire Fighting Service Providers.* Standard 6.2.2 required Airservices to establish, document and maintain a safety management system.

A safety management system is a systematic process for managing safety risks within an organisation. A safety management system provides a structured process for an

[7] 'A service provided [by air traffic control] for the purposes of preventing collisions between aircraft, between aircraft and obstructions, and to expedite and maintain an orderly flow of air traffic' (Manual of Air Traffic Services, November 2002, Part 10. Section. 1. page. 5)

organisation to identify hazards, assess the risks associated with those hazards, and manage resources to control those risks[8].

The Airservices safety management system was documented in the Airservices *Safety Management Manual*. This manual contained policies, accountabilities and responsibilities of senior management, and procedures and guidelines pertaining to safety management within the organisation. The safety management system was comprised of processes for controlling the safety hazards of existing systems, monitoring and reviewing the effectiveness of the system against safety indicators, safety reporting, implementing remedial action, tracking safety issues and conducting internal audits. The manual included guidelines about risk management and the preparation of safety cases.

Essential elements of a safety management system are processes for identifying hazards and monitoring the ongoing risks associated with the hazards. The Australian Standard AS/NZS 4360:1999 (*Risk Management*) states that:

> It is necessary to monitor risks, the effectiveness of the risk treatment plan, strategies and the management system which is set up to control implementation.

The hazard identification and risk monitoring processes of the Airservices safety management system consisted of a number of elements, including an internal audit program; incident reporting, investigation and analysis; and safety cases.

1.16.2.1 Classes of risk

In the Moorabbin risk assessment report, classes of risk were calculated by the consultant in accordance with decision criteria published by the United Kingdom National Air Traffic Services (UK NATS) and were defined in a risk matrix in the risk assessment report. The classes of risks, and their respective definitions, tabled in the risk matrix and that were relevant to the identified hazard scenarios[9] were:

- ‘Class B- risk is undesirable, but may be accepted in exceptional circumstances with the approval of General Manager ATS: contingency plans must be developed.
- ‘Class C- risk may be accepted with the endorsement of the Local Operating Authority: contingency plans and procedures must be developed, and
- ‘Class D- risk is acceptable without any further action.’

1.16.2.2 Hazard scenarios

[8] Civil Aviation Safety Authority, *Safety Management Systems What’s in it for you*, 2002.

[9] The report also described Class A risks as ‘Risk is not acceptable under any circumstances; action is required to treat the risk (p. 6). Class A risks are not included in the report because there were no Class A risks in the Moorabbin MBZ at the time of the accident.

Four perceived hazard scenarios associated with particular phases of flight in the Moorabbin circuit, that were identified in the risk assessment report, were:

- Loss of separation/segregation- aircraft taxiing;
- Loss of separation/segregation following take-off;
- Loss of separation/segregation during final; and
- Loss of separation/segregation during landing and taxiing to apron.

1.16.2.3 Context

Each of those four hazard scenarios were then allocated a level of perceived risk from the risk matrix in the following contexts:

- When the air traffic control tower was open and operating under the procedures that applied before 21 December 1998;
- When the air traffic control tower was open and operating with reduced staffing levels;
- When the air traffic control tower was closed between the hours of 1800-2000 EST in accordance with the proposed change during hours of daylight;
- When the air traffic control tower was closed between the hours of 1800-2000 EST in accordance with the proposed change during hours of darkness.

In the last context, that is MBZ procedures during hours of darkness, the identified class of risk increased from a Class C risk before 21 December 1998, to a Class B risk after 21 December 1998.

1.16.2.4 Risk mitigators

The risk assessment identified five primary risk reduction measures to mitigate the four hazard scenarios applicable when the tower was closed. These were:

- A maximum of five aircraft in the Moorabbin circuit during MBZ hours;
- Traffic to be monitored by all parties involved in the change process, including Airservices, CASA, Moorabbin Airports Corporation (MAC), and industry to ensure compliance with the five aircraft rule[10];

[10] No time period for monitoring was specified in the risk assessment report.

- Pilot education to be conducted relating to the changes;
- The establishment of a flight movement monitoring program to assess any increase in movement numbers in the few hours following tower closure; and
- To give consideration to a means of publicising the ‘5 aircraft rule’ to flying school trainees.

The risk assessment report also identified the following additional risk reduction measure applicable to the four hazard scenarios, but specific to the period when the tower was closed between the hours of 1800-2000 EST:

- MBZ procedures partly compensate for the lack of ATS (provided it could be ascertained that MBZ procedures were appropriate for use in these circumstances).

1.16.2.5 Implementation of risk mitigators

For the mitigation process to be effective, the risk mitigators had to be:

- Implemented, and
- Monitored.

The risk assessment report concluded that only when these risk reduction measures were ‘implemented fully and correctly’[11], would the risks reduce from the Class B risk back to the original Class C risk. Only in these circumstances would there be no step increase in the level of risk associated with either the reduction in the number of controllers employed in the Moorabbin airport ATC tower, or the reduction in tower hours.

Airservices monitored traffic levels outside tower hours on at least two documented occasions between December 1998 and July 2002. Airservices also reported that it had monitored traffic levels on up to 19 undocumented occasions for periods of up to one hour at a time. The first survey covered a random forty hours and monitored traffic in the Moorabbin MBZ between 13 March 1999 and 11 April 1999. Traffic in the Moorabbin MBZ was monitored for an hour on each of 8 and 9 November 1999 and the results documented. Those results indicated to Airservices that there was general compliance with the maximum of five aircraft in the circuit rule. It also verified the Airservices’ estimates used to substantiate the contention that MBZ procedures were appropriate for use at Moorabbin between 1800 and 2000 hours.

Neither the Moorabbin risk assessment report, nor the subsequent safety case and safety case review, identified criteria against which any quantitative assessment of the effectiveness of the implemented risk reduction measures could be evaluated. Despite the documented requirement to do so, Airservices did not develop any contingency plans or procedures to address the Class C risks that the consultant had identified in the risk

[11] Report on a Risk Assessment for Moorabbin Tower Proposed Air Traffic Service Arrangements for Air Services [sic] Australia’ (19 November 1998, p. 9), and Moorabbin Tower Reduction to Seven ATC: Safety Case (February 1999, p. 7).

assessment report. Airservices did not identify classes of risk in its safety case of February 1999 but did refer to those classes of risk in the safety case review of November 2001.

The review of the safety case of November 2001 concluded that 'the level of risk associated with the hazards has not increased'. That review tabled a list of actions that Airservices believed had been taken to implement the risk reduction measures. The table did not list any criteria against which the effectiveness of the risk reduction measures could have been evaluated.

1.17 Tests and research

Not applicable

1.18 Additional information

1.18.1 Overview of MBZ procedures

An MBZ is 'an airspace of defined dimensions, within which pilots must make specified broadcasts'[12]. MBZ procedures applied in designated airspace surrounding one or more aerodromes when an air traffic control service was not provided.

At the time of the accident, the airspace within 3 NM of Moorabbin airport, from ground level to 2,500 ft above mean sea level, was subject to MBZ procedures. *Civil Aviation Regulations 1988* r.163A stated that, 'when weather conditions permit, the flight crew of an aircraft must…maintain vigilance so as to see, and avoid, other aircraft'. That process can be supplemented by other mechanisms that include:

- Mandatory and discretionary radio broadcasts by a pilot to provide location information to other pilots;
- The use of a third party to monitor traffic and provide information and/or advice;
- The use of automatic equipment in aircraft to identify potential conflicts between aircraft, and provide information and/or instructions to the pilot.

Mandatory and discretionary radio broadcasts are the main supplementary mechanisms used by pilots operating in an MBZ to assist them to see-and-avoid other aircraft. To facilitate that, the carriage of a serviceable radio in an MBZ is also mandatory.

Communications by radio between pilots operating in an MBZ enables what is termed 'alerted see-and-avoid'. In contrast, 'unalerted see-and-avoid' is not supported by an alert on the location of another aircraft. The following four radio broadcasts were mandatory when operating in an MBZ:

- a taxi broadcast (when commencing to taxi for take off),

[12] Aeronautical Information Publication Gen 2.2 (28 Nov 2002).

- a broadcast when entering a runway for take off,
- an inbound or transiting broadcast (prior to entering an MBZ), and
- a circuit joining broadcast (when inbound and joining a circuit).

The AIP also stated that ‘pilot discretion should be used in making other than mandatory calls to assist other traffic'. The base call that is customarily made by many of the pilots who operate in the Moorabbin MBZ is a discretionary broadcast made to assist pilots to see and avoid other aircraft and to enhance the safety of operations in the Moorabbin MBZ. A number of flying training manuals also encourage student pilots to broadcast their location once they are established on the base leg.

Interviews with pilots who were operating at Moorabbin at the time of the accident clearly indicated that there was a greater reliance on the alert as a part of see-and-avoid procedures at night. Pilots reported that, in general, they only initiated a visual search for other aircraft on the basis of prior knowledge gained from alerting information provided by other pilots.

1.18.2 Situational awareness

1.18.2.1 Size of circuit pattern

Although the flying school taught its students to fly a consistent circuit size, the size of a circuit pattern can vary and is dependent on a number of factors. Those factors can include aircraft type, operational circumstances, pilot experience, nature of the flight, training requirements, sequencing, weather conditions, airspace limitations, terrain and air traffic control requirements. These operational parameters necessarily mean that different circuit pattern dimensions may occur in any circuit airspace at any given time. In practice, two aircraft that are the same type may reasonably be conducting similar operations using different circuit dimensions. That difference can be significant to the safety of the operations being conducted within the airspace.

A normal circuit pattern in an MBZ is flown at a height of 1,000 ft above ground level (AGL). The pilot of an aircraft would normally reach a height of at least 500 ft AGL on the upwind leg of the circuit, before commencing the turn onto the crosswind leg. While on the crosswind leg, the pilot would normally continue to climb the aircraft to the MBZ circuit height of 1,000 ft AGL. On late downwind and just prior to turning onto the base leg, the pilot prepares for the descent to the landing threshold. The pilot would normally aim to configure the aircraft for a rate of descent such that the turn on to the final approach would be completed no lower than 500 ft AGL.

In the period 1961 to 2002 there were 36 midair collisions, including this accident, in Australia involving general aviation aircraft, 24 of these collisions occurred in the circuit area. At least eight of these collisions involved pilots conducting different sized circuits, but none of the pilots flew circuits that were considered to be contrary to procedures. The circuits flown by the pilots of the aircraft involved in the Moorabbin accident were not considered by the investigation to be contrary to procedures.

Figure 7 is an extract from the radar data of the Moorabbin circuit area over a 2.5 hour period during the afternoon of 29 July 2002, with the tracks of the two accident aircraft leading to the collision (CNW in red and EUH in blue) superimposed. It shows that there were a variety of circuit dimensions flown throughout that period. It also shows that the dimensions of the circuit flown by the pilot of CNW were relatively small, and the dimensions of the circuit flown by the instructor and student pilot of EUH were relatively large by comparison. They were however, both within the range of the circuit dimensions that had been flown during that period. The dimensions of the circuit pattern flown by the instructor and student pilot on board EUH were similar to what was described by the Chief Pilot of the flying school, as the normal circuit size flown by instructors from that flying school.

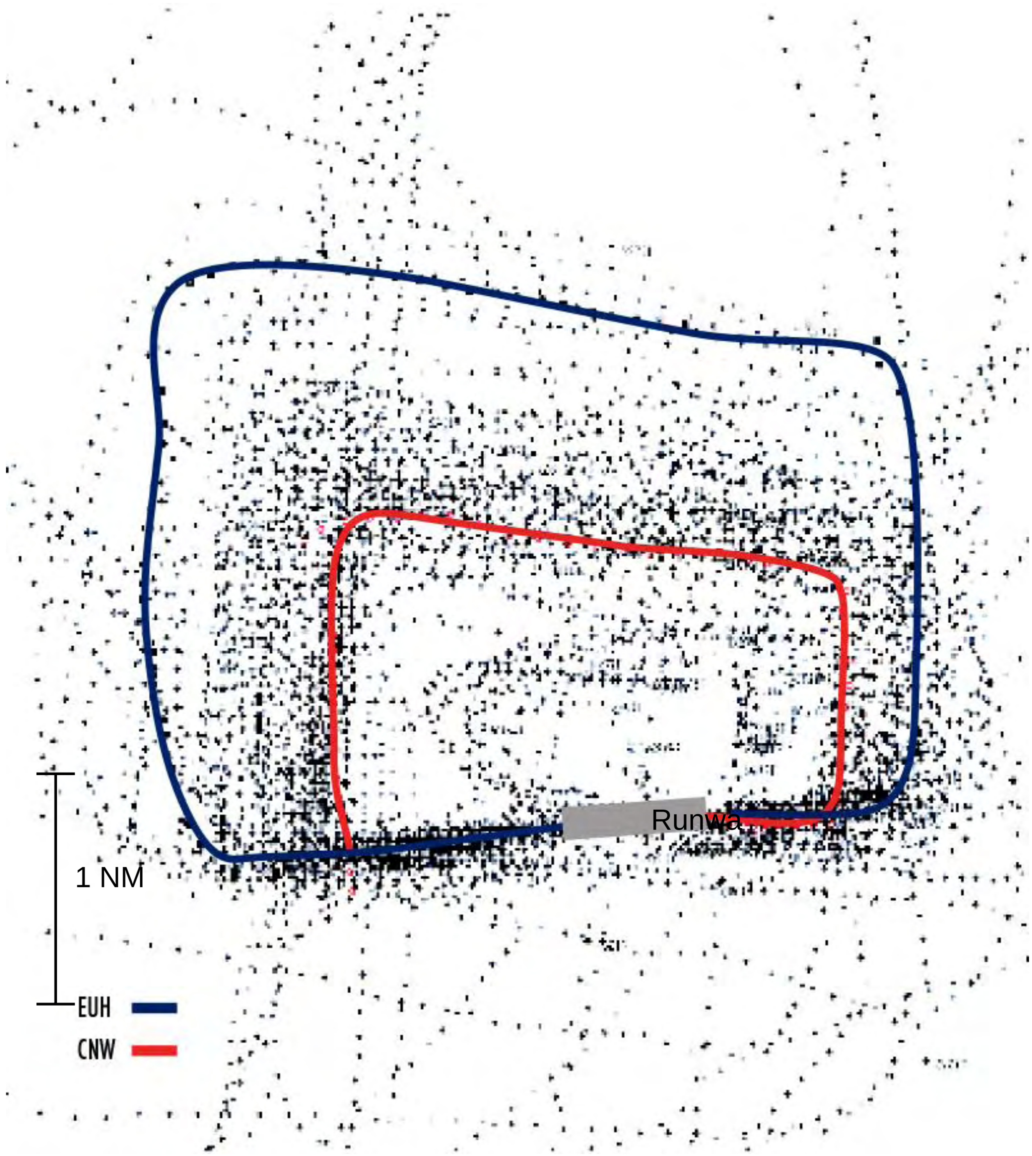

Figure 7: Composite radar plot of the circuit area for Moorabbin runway 17L, between 1300-1500 and 1815-1845 on 29 July 2002, with the accident aircrafts' circuits superimposed.

The dimensions of the circuit flown by the pilot of CNW at Moorabbin before the accident had a downwind leg approximately 1 NM abeam of the runway, and the crosswind and base legs were approximately 2.2 NM apart.

The pilot of CNW had conducted most of her night training at Bankstown airport, before transferring to Moorabbin to continue her flying training. For comparison, Figure 8 shows a radar plot of Bankstown airport aircraft tracks covering a four hour period. It shows that the average circuit had a downwind leg approximately 1 NM abeam of the runway, and that the crosswind and base legs were approximately 2.2 NM apart.

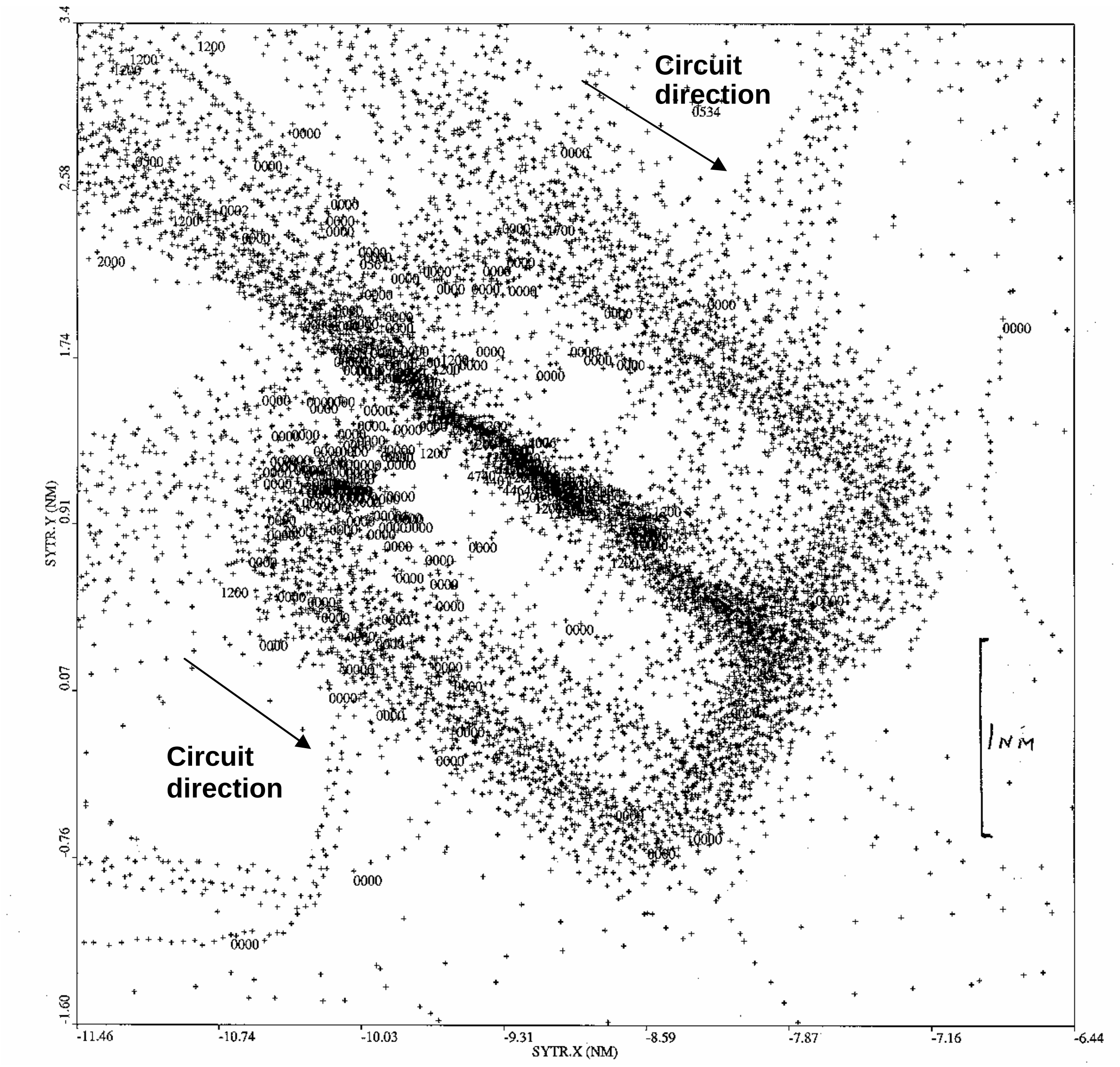

Figure 8: Radar plot of the Bankstown circuit area between 1000 and 1400 on 17 July 2002.

1.18.2.2 Relative locations of EUH and CNW

A pilot's normal field of view from within the cockpit of a C172 is partially obscured by the aircraft's wings and fuselage. Figure 9 shows the approximate relative locations of CNW and EUH, in elevation, from witness reports, when the two aircraft were on final approach.

Figure 9: The relative locations of CNW and EUH on final approach based on witness reports.

Estimations of the likely view of one aircraft from the other aircraft at various times throughout the accident circuit were made. These estimations were then combined with the radar data and estimations of the altitudes of the aircraft at particular locations in the circuit pattern and incorporated into C172 cockpit visibility diagrams.

The result indicated that EUH was most likely visible to the pilot of CNW (that is, in the line-of-sight and not obstructed) while CNW was established on the downwind and base legs of the circuit. EUH was most likely obscured from the view of the pilot of CNW during the turn from the downwind leg onto the base leg and during the turn from the base leg onto the final leg, as the aircraft banked to the left in the turns.

As EUH completed the turn onto final approach, CNW was to EUH's left and higher relative to EUH. CNW would have been obscured to the instructor and student pilot on board EUH by that aircraft's left wing unless the pilot was leaning far forward in his seat to look past the leading edge of the left wing.

During much of the period that CNW was on the downwind and base legs, it was likely that it was not visible (that is, it was not within line-of-sight, or was obstructed by parts of the aircraft) to the instructor and student pilot on board EUH.

Figure 10 depicts the radar track plots from the accident aircraft during their circuit leading up to the accident. The black lines are relative bearings between EUH and CNW. They depict the bearing and distance between the two aircraft at specific times during the circuit leading up to the accident. Point ‘X’ is the approximate location of EUH at the time the pilot reportedly saw CNW. Point ‘Y’ is the location of CNW at that time. Based on ground speed analysis, there is doubt about the accuracy of the last three plots for CNW on its downwind leg, and those plots have not been used.

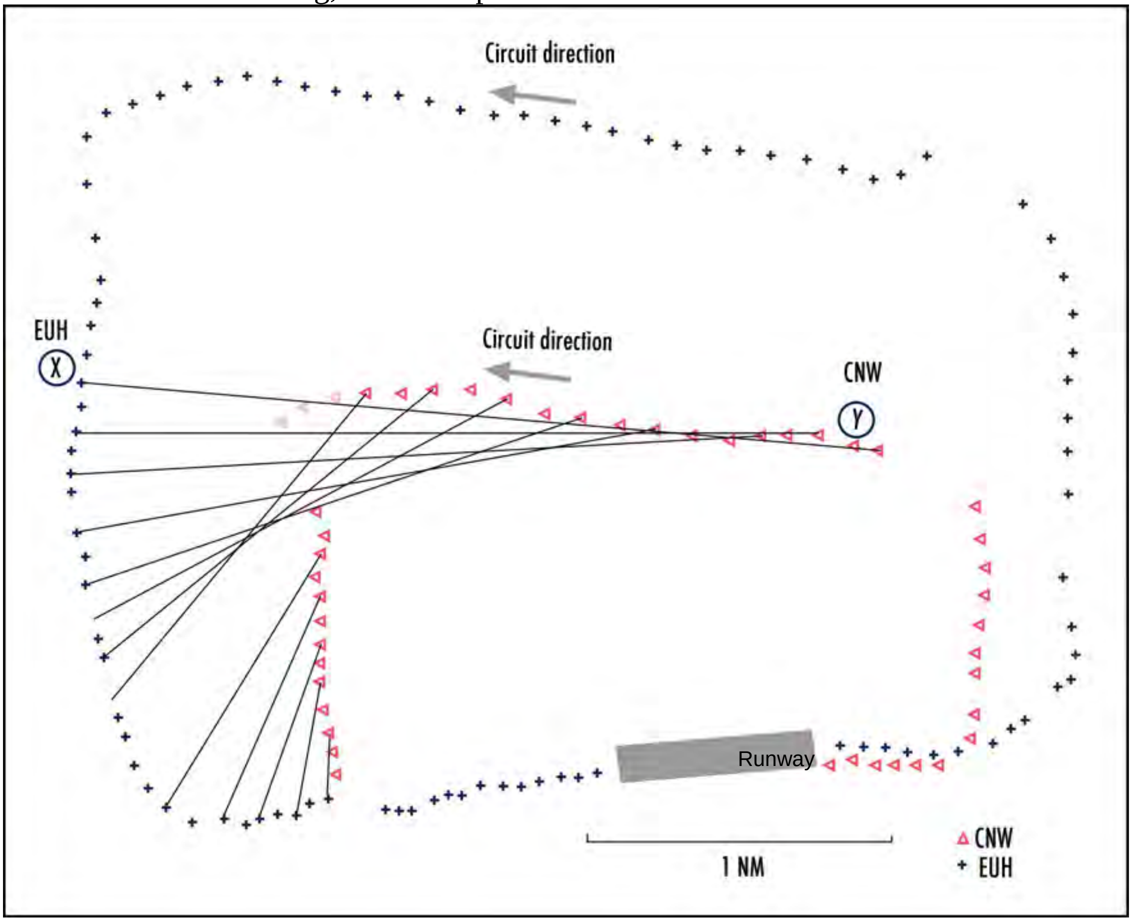

Figure 10: Radar plot of the circuit area, showing the relative bearings between the two accident aircraft before the accident.

It was not possible to use the actual relative altitudes of the two aircraft because of the lack of altitude information available from the radar data. Estimations were therefore made of the descent profiles of both aircraft. These estimations were unable to allow for the effect of flap settings and airspeed on aircraft attitude because the actual flap settings of the two aircraft at various locations throughout the accident circuit could not be accurately established. However, changes in aircraft attitude caused by a change of flap setting may have affected cockpit visibility.

1.18.2.3 Pilots’ awareness of circuit traffic.

During night VFR operations, there is a greater need for a pilot to refer to flight instruments for significant parts of a night circuit instead of looking outside the cockpit, especially during turns. That in-cockpit focus reduces the time, and therefore the opportunity, available for the pilot to see, or to monitor, the progress of potentially conflicting aircraft.

Aircraft are visually identified at night primarily by their navigation lights and anti-collision beacons. Detection is assisted by the movement of the

aircraft lights compared with the background. If the aircraft lighting is superimposed against many background light sources on the ground, and some of those background light sources are themselves moving, aircraft lights will be harder to detect.

Expectancies about what will happen in the near future, and what information will be important in the near future, play an important role in a pilot's situational awareness and decision making.[13] A pilot will look more at those locations or sources of information that are expected to provide useful information, and will do so to a greater extent as more information is expected from those sources.[14] Most of the time these expectancies lead to desired outcomes, but sometimes the environment does not conform to the expectancies, which can lead to problematic situations.

A pilot's expectancies regarding the possible location of other aircraft can come from a number of sources, such as the general flight path of a circuit at an airport, or from traffic information provided by controllers, other pilots or airborne collision avoidance systems. When traffic information is provided, the pilot is said to be acting in an alerted see-and-avoid environment.

During circuit operations it is normal for a pilot to develop a mental model of the disposition of circuit traffic based primarily on a combination of the visual sighting of other aircraft and radio communications. At night, however, the external visual information is degraded because the origin of that visual information is primarily discrete points of light, not identifiable images.

It is also more difficult for a pilot to detect another aircraft at night because of the limitations low light levels impose on the ability of the eye to detect objects. Therefore, an aircraft that poses a threat to the safety of the flight may go undetected by a pilot conducting an appropriate traffic scan even though there are no physical obstructions to the line-of-sight (see appendix A).

Each of the pilots operating in the MBZ at the time of the accident held a Commercial Pilot (Aeroplane) Licence or a higher qualification. None of the pilots operating in the MBZ at the time of the accident had a complete appreciation of the traffic pattern. Pilots operating in the Moorabbin MBZ under the night VFR indicated that they relied on knowledge gained from radio broadcasts to initiate their visual search for aircraft. They did not generally look for aircraft about which they were not aware.

There was no evidence to indicate that the pilots involved in the collision, or any of the other pilots that were operating in the MBZ at the time of the collision, had not made any of the mandatory MBZ broadcasts.

Pilots operating in the Moorabbin MBZ at the time of the accident reported that there was a significant amount of traffic to monitor, in addition to the

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[13] G. Klein, *Sources of Power: How People Make Decisions*, MIT Press, Cambridge, MA, 1999.

[14] C. D. Wickens et al., *The Allocation of Visual Attention for Aircraft Traffic Monitoring and Avoidance: Baseline Measures and Implications for Free Flight*, Technical Report ARL-00-2/FAA-00-2, Aviation Research Laboratory, Institute of Aviation, University of Illinois, 2000.

normal workload associated with their operations. The predominant radio broadcasts made in the Moorabbin MBZ at the time of the accident were the mandatory MBZ broadcasts, and a discretionary base broadcast made by some pilots as they turned onto the base leg; a broadcast that was common at Moorabbin. Other occasional, discretionary, broadcasts were also reported to have been made by some pilots to provide supplementary information. However, there were no routine responses made to any of the mandatory broadcasts, for example, by other pilots in response to a mandatory taxi broadcast made by a pilot about to commence operations in the MBZ. The regulations do not require a pilot to respond to MBZ broadcasts made by another pilot.

The instructor on board EUH, and other pilots operating in the circuit at the time of the accident, considered the time interval between the base broadcasts made by the pilots of the two accident aircraft indicated that they were separated by approximately the distance of a base leg.

The pilots of EUH later reported that they were unaware of the actual location of CNW after the pilot of CNW made the base broadcast.

1.18.2.4 Traffic alerting

The factors that can affect the likelihood of a pilot seeing another conflicting aircraft in sufficient time to 'make the necessary control movements and allow the aircraft to respond' [15], to avoid the conflicting aircraft include:

- foreknowledge of the existence and relative location of the other aircraft;
- the size, conspicuity[16] and speed of the other aircraft;
- the different types and operational characteristics of aircraft operating within defined airspace, and the number of aircraft in that airspace;
- cockpit visibility, 'blind spots' and background contrast;
- the perceived workload of the pilot; and
- fatigue and stress.

[15] Bureau of Air Safety Investigation Research Report (1991) 'Limitations of the See-and-Avoid Principle', p3,

[16] The term 'conspicuity' refers to the visual salience or distinctiveness of an object. It is associated with the physical properties of the object and its background, rather than the observer's visual abilities.

1.18.2.5 Night VFR scan technique

A visual scan technique, especially in a circuit in uncontrolled airspace, may be more effective if the scan concentrates on areas of the circuit that pose the greatest potential threat to the safety of the flight. The extended runway centreline along the final approach path is one main area for concern as aircraft converge towards the landing threshold. Once an aircraft commences a turn onto base leg, especially at night, the time available for the pilot to visually scan for traffic reduces due to cockpit workload.

When a turn is initiated from base leg onto final approach under the night VFR, the pilot would normally refer to instruments to maintain aircraft attitude during the turn. The pilot would then refer to the runway lights to ensure that the aircraft was aligning correctly with the extended centreline of the runway. Normally, when the aircraft is established on final approach, the pilot would primarily refer to the view of the runway, and cross refer to the aircraft instruments for airspeed information. At that time, the focus of the pilot's scan is predominantly toward the runway. There may be no perceived requirement for the pilot to scan elsewhere because an assessment of the relative locations of other circuit aircraft would have been made before commencing the turn onto both the base leg and the final approach.

1.18.2.6 Aircraft lighting

The flying school’s procedures for conducting night operations stated that the aircraft's landing lights were to be continuously switched on during circuit operations. The landing light on EUH was inoperative, and the aircraft was flying with its taxi light illuminated instead. The landing light and the taxi light are both 100 watt lights with the same type of reflector, mounted side by side in the leading edge of the left wing. The taxi light is angled down 0.5 degrees compared with the landing light. Both lights point downwards in normal flight, so that the runway will be illuminated during the approach to land. The use of the landing light instead of the taxi light was not considered by the investigation to be significant.

The flashing strobe lights of both aircraft were reported by witnesses to be operating just before the accident.

1.18.3 Fatigue

The pilot of CNW had been working long hours in the days before the accident, in preparation for an aviation theory examination that was successfully undertaken at 0830 on the morning of the day of the accident. Later that afternoon the pilot carried out an aerobatic flight check. Shortly before the accident flight the pilot of CNW had reported, to a colleague, of being fatigued.

To determine whether a given human performance aspect, in this case fatigue, may have been significant in the development of an occurrence there are two main tests that must be applied; those tests are for existence and influence. In order to determine whether fatigue affected the pilot of CNW and was a factor in this occurrence, it would be necessary to both show that the pilot was most likely fatigued, and that some action or omission by the pilot may have been attributable, in whole or in part, to fatigue.

In qualitative terms, the schedule of work and study of the pilot in the days leading up to the accident may have been conducive to a moderate level of fatigue. In addition, the pilot reported to a colleague of feeling fatigued. However, given the unstructured nature of the pilot's work/study situation, there was not sufficient work-rest data available to carry out a quantitative assessment of possible pilot fatigue (for example by using the Centre for Sleep Research, Fatigue Audit InterDyne (FAID) program).

Information about the pilot's behaviour during the circuit leading up to the accident was limited to witness reports and recorded radar data. That information did not indicate any aspect of the operation of the aircraft that could be attributed to pilot fatigue.

2 ANALYSIS

2.1 Introduction

Although some of the contributing factors which may be identified during any safety investigation are associated with actions of individuals or organisations, it is essential to note that a key objective of a safety investigation is to identify safety deficiencies or weaknesses in a system and to learn how to minimise the risk of future occurrences. Whether risk mitigators are put in place generally necessitates a risk assessment process involving cost-benefit analysis. Although the investigation identified some deficiencies relating to the reduction in Moorabbin tower hours, it could not be determined whether the reduction in tower hours contributed to the accident. The process of the implementation and evaluation of risk mitigators used by Airservices has been included in this report, because the deficiencies were identified during, and are part of, this investigation.

Most accidents result from a combination of contributing factors. The broad areas analysed during the investigation were:

- Circuit procedures- the operational and safety consequences of different sized circuits that may have led to mis-perceptions about the location of other aircraft in that circuit in the absence of a visual sighting;

- Human factors- the human tendency to accept information that supports a pilot's situation assessment, rather than critically re-evaluate the information on which that situation assessment was based;

- Airspace management- the evaluation of risks associated with the reduction in the Moorabbin airport air traffic control tower hours of operation.

In this accident scenario, the pilot of CNW commenced the turn onto the base leg of the circuit when EUH was about to commence a turn onto a longer final approach. The relative locations of the two aircraft at that time placed them on a potential collision course. That would have been apparent to both the instructor and student pilot on board EUH and to the pilot of CNW, had any of them been aware of the location and intentions of the other aircraft at that time. It is unlikely that the pilot of CNW was aware of the location of EUH at, or subsequent to, the time the pilot of CNW made the decision to turn onto base leg.

The pilot of CNW flew a smaller circuit pattern than the instructor and student pilot on board EUH, and therefore CNW took less time than EUH to complete the circuit. While the dimensions of the circuits flown by the two accident aircraft were not unusual, the consequent difference in the elapsed time taken to conduct the circuits had the unintended result of removing the natural spacing provided by the difference in the take-off times.

When CNW became established on final approach, it was above EUH. It is likely that the pilot of CNW and the pilots of EUH were aiming for a similar touch-down point in the vicinity of the threshold of runway 17L. That would have required a higher rate of descent from CNW than EUH.

In the absence of any other defence or action, the difference in circuit dimensions and the different rates of descent resulted in the two aircraft converging on final approach to runway 17L. The debris along the undershoot area of runway 17L indicated that the aircraft had collided while in the air on final approach to runway 17L.

The investigation could not determine whether the pilot of CNW heard any of the broadcasts made by the other pilots operating in the MBZ just prior to the accident, other than the alert issued by the pilot of JSN, nor to what extent those broadcasts influenced the situational awareness of the pilot of CNW.

2.2 Situational awareness

2.2.1 Introduction

The pilots in both aircraft were relying on the principle of see-and-avoid for the establishment and maintenance of separation in the Moorabbin MBZ. See-and-avoid in this environment is enhanced by a radio alert on the existence and location of other aircraft. If there is no alert, if the alert is inaccurate, or if the alert is mis-interpreted, then there is less likelihood that a pilot will see, and therefore be able to avoid another aircraft. Also, if the alerting information is wrong or misleading, the attention of the pilot searching for other aircraft can be diverted from the direction or location of a target aircraft. If a pilot is unable to adequately assimilate the information being provided by other pilots, then the situational awareness of that pilot may be incomplete. Any decisions made by a pilot about the potential threat to the safety of an aircraft based on that information, in the absence of seeing the relevant aircraft, would be flawed and may compromise flight safety.

2.2.2 Pilot's awareness of circuit traffic

The instructor and student pilot of EUH continued their approach to the runway when they heard the pilot of CNW make a base broadcast. They were satisfied that CNW was adequately spaced behind them in the circuit pattern. That belief was based on the time interval between the respective base broadcasts and their perception of the location of CNW at the time the pilot made the base broadcast.

The pilot of CNW most likely did not see EUH while conducting the turn onto the base leg or final approach, or subsequently. Although traffic information will generally increase the likelihood of a pilot detecting a target aircraft, it can also decrease the likelihood of detection if the pilot sights the wrong aircraft and therefore has an incorrect perception of the disposition of other aircraft. In such situations, the pilot may then be less likely to conduct additional scanning, because they believe their perception to be correct. If the pilot of CNW saw EUC on short final, instead of EUH on an extended final approach, before commencing the turn from downwind onto base, she may have either thought that EUC was EUH or was unaware of EUH. In either situation, it was likely that she assessed that there was no collision risk.

Little or no additional monitoring of the other aircraft's location would have been considered necessary by any of the pilots, if they believed they already had accurate situational awareness. There were no subsequent triggers that may have caused either of the pilots to critically re-evaluate their perception of the location of the other aircraft.

2.2.2.1 Cockpit visibility from EUH

There were limited opportunities for the instructor and student pilot to see CNW during the accident circuit due to cockpit visibility limitations that resulted from the relative position of CNW throughout that circuit.

2.2.2.2 Cockpit visibility from CNW

The estimated difference in height above ground between the aircraft indicated that EUH would most likely have been visible to the pilot of CNW while CNW was on the downwind and base legs of the circuit.

During the turn from downwind onto the base leg of the circuit, the cabin and engine cowling may have obscured EUH from the view of the pilot of CNW. Also, she would probably have been directing a significant amount of attention on aircraft instruments to maintain control of the aircraft during that turn.

During the turn from the base leg onto final approach, the pilot of CNW would probably have again been directing some attention to aircraft instruments to maintain control of the aircraft during that turn. It is also likely that EUH was obscured from the pilot of CNW due to cockpit visibility restrictions during the left turn onto final approach.

It was unlikely that the operation of EUH's taxi light, instead of the landing light, limited the ability of the pilot of CNW to detect EUH.

2.2.2.3 Cockpit visibility on final approach

Once both aircraft were established on final approach, it would have been difficult for either of the pilots to see the other aircraft because they were largely obscured from the view of each other by parts of their own aircraft for a significant period of time.

2.2.3 Size of the circuit pattern

The size of the circuits flown by each aircraft was significantly different. Even if the pilot of CNW had heard the base broadcast by the instructor and student pilot of EUH, it would not have provided an accurate alert of the location of that aircraft on which the pilot of CNW could have based a visual search. Similarly, the provision of the base broadcast by the pilot of CNW would not have provided an accurate alert of the location of that aircraft on which the instructor and student pilot of EUH could have based a visual search

because their perception of the location of CNW based on the timing of the base broadcast and their understanding of the size of the circuit the pilot of CNW would have been flying, differed from the actual location of CNW.

It was reasonable for the instructor and student pilot on board EUH to have considered that CNW was approximately one circuit leg behind them, because the pilot of CNW made a base broadcast approximately 60 to 90 seconds after the pilots of EUH made their base broadcast. All pilots involved in the accident were from the same flying training school, so there may have been an expectation that they were all flying a circuit of similar dimensions. As 60 to 90 seconds between the base broadcasts would have indicated adequate circuit spacing in those circumstances, the instructor and student pilot on board EUH did not actively search for CNW, concentrating instead primarily on the airspace ahead of them and on flying the final approach.

Similarly, had the pilot of CNW heard the base broadcast made by the instructor and student pilot of EUH, it would also have been reasonable for her to have considered that EUH was approximately one circuit leg in front because her possible perception of the location of EUH based on the timing of the base broadcast and her understanding of the size of the circuit the pilots of EUH would have been flying, probably differed from the actual location of EUH.

Although the two aircraft were being operated by pilots from the same school where a standard circuit size is taught, rigid adherence to a standard circuit size could also be problematic if a pilot is required to deviate from that standard circuit size for operational reasons.

2.3 Airspace safety management

The Airservices safety management process associated with the changes of 21 December 1998 did not specify any criteria against which the identified risk reduction measures could be evaluated, to determine the extent to which those measures ensured that there was no step increase in risk, as a result of the reduced ATC staffing levels and hours of operation at Moorabbin airport. Therefore Airservices could not know whether the risk reduction measures had prevented a step increase in the risks posed by the reduction in tower staffing and the consequent reduction in tower hours.

Airservices could not know whether the class of risk assigned to each of the hazard scenarios identified in the risk assessment report for MBZ operations between the hours 1800-2000 EST, and after dark, had been mitigated from a class B risk to a class C risk, because either;

- the risk mitigators were not implemented; or

- the risk mitigators were not monitored for effectiveness

That either resulted in a step increase in the perceived level of risk assigned to the hazard scenarios posed by the increase in MBZ hours, or Airservices, at the very least, was not able to determine whether the risk had been appropriately mitigated. ‘Risks and the effectiveness of control measures need to be monitored to ensure changing circumstances do not alter risk priorities’ (The Australian Standard AS/NZS 4360:1999 *Risk Management)*, and to ensure that those risk mitigators achieve the expected levels of risk reduction.

Class B risks required the approval of the Airservices General Manager Air Traffic Services (ATS) and the development of contingency plans. Airservices did not perceive that any Class B risks existed at Moorabbin and consequently did not seek approval from the General Manager and did not develop contingency plans.

The Class C risks identified by the risk assessment report, and incorporated into the Airservices safety case, were acceptable if contingency plans and procedures were developed. No contingency plans or procedures were developed to address the Class C risks identified by the consultant and incorporated into the Airservices safety case, for the reduction in tower hours at Moorabbin airport.

The mitigator of a maximum of five aircraft in the circuit could not be effectively implemented, because notification of the instruction in the ERSA and random monitoring of traffic movements in the airspace could not ensure compliance. As the mitigation of risk to acceptable levels in accordance with the risk assessment report was dependant on all risk reduction measures being implemented, any non-compliance with that risk mitigator would result in a step increase in the risk posed by the reduction in tower hours. The investigation could not determine whether these deficiencies contributed to the accident.

Airservices undertook a written assessment of MBZ procedures, in accordance with the risk assessment report, and determined that MBZ procedures were appropriate to cover traffic levels expected at Moorabbin airport when the tower was closed.

2.4 Fatigue

The investigation could not establish any aspect of the conduct of the flight by any of the pilots involved in the accident that would link the possible effects of fatigue with the accident sequence.

2.5 Summary

It is unlikely that any of the pilots involved in the accident were aware of the proximity of the other aircraft before the accident. The pilots were relying on alerted see-and-avoid to enhance the safety of their operations in the Moorabbin MBZ. Given the difference in the circuit dimensions flown by the pilots of EUH and CNW, it is likely that the alerts provided by the discretionary base broadcasts were not adequately assimilated by the pilots of those aircraft. Pilots rely on alerted see-and-avoid to assist them with accurate situational awareness. However, if pilots are unable to assimilate information being provided by other pilots, then the potential risk of a collision resulting from inadequate situational awareness is increased.

Human performance limitations in the '…visual scanning process can reduce the chance that a threat [potentially conflicting] aircraft will be seen and successfully evaded. These human factors are not "errors" nor are they signs of "poor airmanship". They are limitations of the human visual and information processing system which are present to various degrees in all pilots'[17].

Consequently, the practice of routinely re-analysing the information on which decisions are made, especially in airspace where the potential for a confliction is relatively high, might help to compensate for those inherent human performance limitations in the human visual and information processing system. An awareness of those limitations among pilots may also reduce the likelihood that the information is misinterpreted.

Although Airservices reported that MBZ procedures came under the jurisdiction of CASA, Airservices had a responsibility to ensure that any safety criteria in that airspace were met. Airservices had no criteria against which the appropriateness of the risk mitigators could be determined before they were implemented, nor were there any criteria against which their effectiveness in mitigating risk, once implemented, could be evaluated. Therefore, Airservices could not know whether the level of risk assessed for each hazard scenario, before the reduction in tower hours, remained unchanged after tower hours were reduced.

The findings from this investigation should promote a greater awareness among pilots of some of the hazards associated with flying in similar circumstances. The resilience of the aviation system to these kinds of events will be improved if pilots actively and critically re-evaluate the information on which they base their decisions, on a regular basis. An ability to recognise those situations where safety could unknowingly be compromised without that critical re-evaluation would provide a defence against safety infringements.

[17] Bureau of Air Safety Investigation Research Report (1991) 'Limitations of the See-and-Avoid Principle' p3.

3 Conclusions

3.1 Findings

Sequence of events

1. Left circuits using runway 17 left, in the 164 degrees M direction were in use at Moorabbin at the time of the accident.

2. There was a student pilot and an instructor on board EUH. The pilot of CNW was the sole occupant of that aircraft.

3. The pilots of EUH and CNW were conducting circuit training operations under the night VFR.

4. The dimensions of the circuit flown by the pilots of EUH were larger than the circuit dimensions flown by the pilot of CNW.

5. The dimensions of the circuit flown by the pilots of EUH were within the range of circuit dimensions that had been flown at Moorabbin on that day and were similar to what was described as the normal circuit size flown by instructors from that flying school.

6. The dimensions of the circuit flown by the pilot of CNW were within the range of circuits that had been flown at Moorabbin on that day and were not considered to be contrary to procedures.

7. The pilots of EUH made a base broadcast when they were established on the base leg of the circuit. Other pilots in the MBZ, as well as the pilots of EUH, heard the pilot of CNW make a base broadcast.

8. When CNW was established on base leg and EUH was established on a long final approach there was another C172 aircraft, EUC, also established on final approach between both EUH and CNW and runway 17 left.

9. EUH and CNW converged on the final approach and collided while still in the air, but close to the ground. Both aircraft were destroyed by the post impact fire.

10. The instructor and the student pilot of EUH escaped from the burning wreckage. The instructor received minor injuries and the student pilot was not injured.

11. The investigation was unable to determine why the pilot of CNW was not able to evacuate the aircraft.

12. The pilots of EUH reported that the aircraft was operating normally at the time of the accident.

13. There was no evidence that CNW was affected by fuel contamination or mechanical malfunction.

Personnel

14. The pilots in command of EUH and CNW were appropriately licensed and held current and valid medical certificates.

15. There was no evidence that indicated that any of the pilots involved in the accident was not fit to pilot an aircraft.

Operating environment

16. Aircraft were operating in the Moorabbin airspace under MBZ procedures.

17. In December 1998, the MBZ hours of operation at Moorabbin were increased as a result of a reduction in the number of controllers employed in the Moorabbin air traffic control tower and a consequent reduction in control tower hours of operation.

18. The accident occurred after dark and in those hours during which the tower would have been operating and an air traffic control service would have been provided, prior to December 1998.

19. The Moorabbin Air Traffic Control Tower was not in operation at the time of the accident.

20. The investigation could not determine whether the reduction in tower hours contributed to the accident.

3.2 Significant factors

- The different circuit dimensions negated the natural spacing provided by the difference in take-off times, even though both EUH and CNW were the same aircraft type and were operating in the circuit at similar speeds.

- The broadcasts made by the pilots of EUH and CNW did not sufficiently assist their situational awareness.

- None of the pilots involved in the accident saw the other accident aircraft in sufficient time to enable either of them to avoid the collision.

4 Safety Action

4.1 Local safety action

4.1.1 Flying School local safety action

Prior to the accident, the operator required company instructors and student pilots to make a base broadcast at the start of the base leg of the circuit. Subsequent to the accident, the operator has amended the content of that broadcast. Company instructors and student pilots are now required to append their perceived position in the landing sequence to the base broadcast. This is normally accomplished by the use of a phrase such as ‘number one’ or ‘number two’, depending on whether the pilot considers himself/herself to be the first or second aircraft respectively in the landing sequence.

4.1.2 Airservices Australia local safety action

In September 2002, Airservices approved a plan for an ongoing Airport Movement Review Outside Tower Hours for ATC towers that were not open 24 hours per day, which included Moorabbin tower, to monitor the need for an air traffic control service. The review will gather aircraft movement statistics three times per year during the months of February/March, June/July and October/November, and commenced in October 2002. Those aircraft movement statistics are to include a representative spread of possible out of hours air traffic movements. Each collection period is to cover at least two hours, in visual meteorological conditions where possible.

During 2003, Airservices modified its Safety Assessment for Change documentation[18] to reflect both the changes to the regulatory framework within which Airservices operates, and to improve Airservices’ change practices. Within those documents, a number of references are made to the monitoring of the effectiveness of risk mitigators. These include;

- The need to maintain and update the safety case with information from any review following implementation of change
- The need to confirm the operational safety performance of the system following any change and the monitoring of any identified concerns on an ongoing basis
- The requirement for a Post Implementation Review which is to include measures that will enable the success of the change process to be determined
- Articulating the importance of specifying risk controls as clearly as possible, and in a way that their effectiveness can be measured to gauge the progress made towards meeting the total operational safety requirement
- To identify, and include involvement from, other relevant stakeholders including pilots and other industry sources

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[18] Airservices Australia, *AA-NOS-SAF-0104, Safety Case, Safety Assessment Report and Safety Statement Preparation*, 7 July 2002, and *Airservices Australia, AA-NOS-REC-0105, Safety Assessment*, 28 April 2003.

- The role of line managers to identify the need for, and conduct, a review of the original safety case on which change was based
- The ongoing review of risk levels associated with significant change
- An internal review of hazard identification practices to identify any deficiencies in practice, documentation or software debugging tools. This review will drive the development of a National Operating Standard on the aspect of the Safety Management System that will regulate the need within Airservices for ongoing hazard identification.

The Safety Assessment for Change documentation suite will be reviewed in 2004 so refinements can be made to address any identified deficiencies.

4.1.3 ATSB local safety action

A summary of the investigation report will be included in the ATSB supplement of a future issue of Flight Safety Australia, and the full report will be published on the ATSB's web site www.atsb.gov.au.

The Australian Transport Safety Bureau will be publishing a discussion paper in the next few weeks entitled '*Review of mid-air collisions involving general aviation aircraft in Australia between 1961 and 2002'*.

Appendixes

Appendix A: A review of see-and-avoid issues associated with the collision

A.1.1 Introduction

To see and avoid another aircraft requires a pilot to perform a number of tasks. The ‘see’ component involves the following steps:

- Search: the pilot looks outside the aircraft, and searches the available visual field. This search may or may not be in response to a traffic alert, or based on previous information about another aircraft’s position.

- Detection: the pilot may detect possible target aircraft or objects of interest.

- Identification: if an object is detected, it is then examined to determine if it is an aircraft or other potential collision threat.

The ‘avoid’ component involves the following steps:

- Threat assessment: if an object is identified as an aircraft, its altitude, heading and speed must be assessed to determine whether or not it is a collision threat.

- Development of an avoidance plan: if the aircraft is assessed as a collision threat, a decision must be made as to what type of response is appropriate.

- Avoidance response: the pilot must initiate the necessary control movements to take evasive action. There will also be a time period required for the aircraft to respond to the pilot’s input and move away from a collision path.

For each of these six steps, there are many factors that can limit the timeliness and effectiveness of pilot performance. The ‘avoid’ component described above was not relevant to this accident because the pilots involved in the accident did not sight the other aircraft and therefore had no opportunity to ‘avoid’ it.

Further information on the limitations of see-and-avoid is provided in a number of sources, including the Bureau of Air Safety Investigation[19] 1991 research report *Limitations of the See-and-Avoid Principle*, which was used as the primary reference for this review.[20] There is a range of individual factors that can influence see-and-avoid performance, such as fatigue, stress and visual ability. These issues are not discussed in

[19] The Bureau of Air Safety Investigation (BASI) became part of the newly formed Australian Transport Safety Bureau (ATSB) on 1 July 1999.

[20] The BASI report made six recommendations including ‘… The CAA should take into account the limitations of see-and-avoid when planning and managing airspace and should ensure that unalerted see-and-avoid is never the sole means of separation for aircraft providing scheduled services’. In 2003, the ATSB classified the CASA response to that recommendation as CLOSED – ACCEPTED on the basis that CASA agreed that the limitations of see-and-avoid should be taken into account when planning and managing airspace and the Authority had indicated that appropriate risk management techniques will be used to establish airspace regulatory safety requirements. The ATSB agreed that the use of the absolute ‘never’ was overtaken by risk assessment.

this review but, where potentially relevant, they are discussed in the main body of the report.

A.1.3 Speed of relative movement

The average person has a field of vision of 190 degrees, but the quality of vision varies across the visual field. Around the centre of the retina, or the 'line of sight', acuity and colour vision are sharpest. Acuity then rapidly decreases as the target moves further from the line of sight. Sensitivity to movement also decreases as the target moves further into the periphery. However, the decrease in sensitivity to movement is less than the decrease in acuity, and movement can therefore appear to be more salient in the peripheral visual field.[21]

Overall, target detection ability increases with increased velocity of the target across the visual field.[22] The threshold for detecting motion under ideal laboratory conditions has been reported as 1-2 arc minutes/second when stationary reference objects are present near the target, and 10-20 arc minutes/second when there are no such reference objects.[23] Visual acuity decreases as target velocity increases, particularly at speeds greater than 20 degrees/second, but there is reportedly no effect on acuity for speeds less than 2.5 degrees/second.[24]

A.1.4 Nature of visual search

Unless a target aircraft has a high level of conspicuity, a pilot will need to search for it. Eye movements during a search occur in rapid jerks called 'saccades', interposed with brief rest periods called 'fixations'. Information is only obtained from the visual scene during fixations. The individual eye movements associated with visual search take a small but significant amount of time. At most, the eyes can make about three fixations per second, but when scanning a complex scene more time is usually taken with each fixation.

According to the Bureau of Air Safety Investigation research Report (1991, pp 6-7),

> 'Quality of vision varies across the visual field, largely in accord with the distribution on the retina of the two types of light sensitive cells, rods and cones. Cones provide sharp vision and colour perception in daylight illumination and are concentrated at the fovea, the central part of the retina on which an object appears if it is looked at directly. Rods are situated on the remainder of the retina surrounding the fovea on an area known as the peripheral retina. Although rods provide a black and white image of the visual field, they continue to operate at low light levels when the cones have ceased to function.'

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[21] K. R. Boff & J. E. Lincoln, *Engineering Data Compendium*, Wright Patterson Air Force Base, Ohio, 1988, section 5.205.
[22] K. R. Boff & J. E. Lincoln, *Engineering Data Compendium*, Wright Patterson Air Force Base, Ohio, 1988, section 1.624.
[23] C. H. Graham, 'Perception of movement', in *Vision and visual perception,* eds C. H. Graham et al., 1966, pp. 575-588.
[24] K. R. Boff & J. E. Lincoln, *Engineering Data Compendium*, Wright Patterson Air Force Base, Ohio, 1988, section 1.603.

> '…at night, acuity is greatest in the peripheral retina.'

In general, visual scans tend to be unsystematic, with some areas of the visual field receiving close attention while other areas are neglected. Areas of the sky near the edges of windscreens are generally scanned less than the sky in the centre, and saccades may be too large, leaving large areas of unsearched space between fixation points.

Accordingly, it would have been possible for the pilot of CNW to conduct an active, conscious scan for aircraft prior to both the turn from downwind onto base leg, and from base leg onto the final approach, and at other times throughout the circuit, and not have detected EUH during those scans because of the physiological limitations of the eye and the limitations that darkness imposes on the eye.

A.1.5. Visual scanning technique

A number of recommendations have been made with regard to effective search strategies. For example, The US Federal Aviation Administration (FAA) *Aeronautical Information Manual* (section 8.1.6) recommended that visual flight rules (VFR) pilots should spend most (about 70 to 75%) of their time looking outside the aircraft and only a small amount of time looking inside the cockpit. Recent research has found that pilots generally spend 30-35% of their time looking outside in situations mimicking VFR conditions and conditions mimicking instrument flight rules conditions in visual meteorological conditions.[25]

In more specific guidance material, the FAA *Advisory Circular 90-48C* (Pilots' Role in Collision Avoidance) recommended that pilots use a series of short, regularly spaced eye movements not exceeding 10 degrees, with each area being observed for at least 1 second to enable better detection. A problem with such a method is that it would take 54 fixations to scan an area 180 degrees wide and 30 degrees vertical. The United Kingdom Civil Aviation Authority (CAA) has endorsed the FAA recommended technique, but suggested that the main area of focus should be at least 60 degrees left and right and at least 10 degrees above and below the projected flight path.[26]

Although various overseas organisations have published guidance material regarding types of effective scanning techniques, there is currently no such formal advisory information provided to pilots in Australia. The Civil Aviation Safety Authority has published two articles on scanning in its *Flight Safety Australia* magazine. The first article, titled 'Collision Course' in the November-December 1999 issue, contained guidance information on scanning from the UK CAA brochure. The second article, titled 'Eye on the sky' in the September-October 2003 issue, was adapted from a US Aircraft Owners and Pilots Association article about avoiding midair collisions.

Although guidelines on the use of scanning techniques have a sound theoretical basis, the investigation did not identify any research that systematically assessed their effectiveness for improving aircraft detection.

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[25] C. D. Wickens et al., *Mid Air Target Detection: What Makes it Difficult? Application of Attention and Situation Awareness Model*, Technical Report ARL-01-9/NASA-01-5, Aviation Research Laboratory, Institute of Aviation, University of Illinois, 2001.

[26] Civil Aviation Authority, *Collision Avoidance*, General aviation safety sense leaflet 13A, CAA, UK, 2000.

In general, traffic information will increase the likelihood of a pilot detecting a target (Andrews, 1991). Based on these results and other studies, Andrews developed a mathematical model of cumulative detection probability over time for a target on an interception course. A key component of the model was the 'search effectiveness parameter'. Values of this factor that he estimated based on his experiments and other trials were:[27]

- 17,000/steradian-second[28], when general aviation pilots flew in an unalerted, enroute environment (1991 study);
- 34,000/steradian-second, when professional pilots were more alert and expecting another aircraft, but not provided with any specific traffic information;
- 90,000/steradian-second, when general aviation pilots were provided with a traffic advisory display showing target bearing to the nearest 30 degrees; and
- 130,000/steradian-second, when professional pilots were using a TCAS, which provided target bearing within approximately 8 degrees.

In other words, search effectiveness can vary depending on the level of pilot alertness as well as the amount of traffic information provided. Although traffic information will generally increase the likelihood of a pilot detecting a target aircraft, it can also lead to problems if the pilot sees the wrong aircraft.

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[27] J. W. Andrews, *Air-to-Air Visual Acquisition Handbook*, Project Report No. ATC-151, 1991. Washington, DC: FAA, 1991.

[28] A steradian is a unit of angular area. It is equivalent to approximately 12,000,000 arc minutes squared. It is the relative values between the scenarios that are important rather than the actual nature of the unit used.

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