Australian Government
Australian Transport Safety Bureau

Mid-air collision involving Piper PA-44-180 Seminole, VH-JQF and Beech D95A Travel Air, VH-AEM

8 km south of Mangalore Airport, Victoria on 19 February 2020

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Addendum

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Safety summary

What happened

Around midday on 19 February 2020 a Beech D95A Travel Air, registered VH-AEM, and a Piper PA44-180 Seminole, VH-JQF, collided mid-air approximately 8 km south of Mangalore Airport, Victoria. The Travel Air was approaching Mangalore Airport from the south, on descent to conduct a practice instrument approach, while the Seminole was southbound on climb from Mangalore to Essendon Airport.

Both aircraft were operating under the instrument flight rules (IFR) in non-controlled airspace. The pilots of each aircraft had been provided with traffic information about the other aircraft prior to the collision, in accordance with procedures. Both aircraft were fitted with dual radios. Other pilots monitoring the common traffic advisory frequency (CTAF) associated with Mangalore Airport reported hearing pilots from both aircraft broadcast but had no recollection of hearing them speaking directly to each other.

The two aircraft collided with no evasive manoeuvring identified in recorded flight data. All four pilots were fatally injured and both aircraft were destroyed.

What the ATSB found

This was the first mid-air collision between two civil aircraft operating under the instrument flight rules and procedures that have been in place in Australia for decades.

The ATSB identified that, following receipt of verbal traffic information from the controller, the pilots did not successfully manoeuvre or establish direct communications on the CTAF to maintain separation, probably due to the collision risk not being recognised.

While it is probable that the aircraft were in instrument meteorological conditions at the time of the collision due to the presence of extensive cloud, the known limitations of the 'see-and-avoid' principle meant that the pilots were unlikely to have seen each other in sufficient time to prevent the collision even in clear weather conditions.

Additionally, following receipt of an alert indicating the developing proximity of the aircraft, the controller assessed it in accordance with the required procedure. However, after considering that the pilots were aware of each other's presence and were required to ensure their own separation in non-controlled airspace, the controller did not intervene further.

While the pilots were responsible for self-separation within the Mangalore CTAF area, they did not have access to radar or automatic dependent surveillance broadcast (ADS-B) information. As a result, the pilots were required to make timely decisions to avoid a collision without the best available information.

Finally, although not contributory to the accident, the ATSB identified that the wording of procedures relating to the conduct of practice instrument approaches at Mangalore Airport resulted in varied application and an increased risk of traffic conflicts.

What has been done as a result

Airservices Australia (Airservices) have proposed a change to the Civil Aviation Safety Authority (CASA) to introduce a surveillance flight information service (SFIS) around Mangalore Airport, designed to provide enhanced traffic information services to all aircraft operating in a 20 NM radius of the airport. The proposed service would require all aircraft to broadcast on the CTAF within the broadcast area, while providing a dedicated air traffic controller operating on the CTAF to provide a flight information service utilising surveillance.

By listening on the CTAF, the controller would be able to determine whether aircraft have arranged their own separation following receipt of traffic information and provide updated traffic information if required. A similar service was introduced around Ballina Airport in August 2021.

In September 2021, the CASA Office of Airspace Regulation (OAR) announced an aeronautical study into the airspace within a 25 NM area of Mangalore Airport, up to an altitude of 8,500 ft. The scope of this study involves:

- a review of traffic type and density over the previous 5 years
- an evaluation of the suitability and efficiency of the airspace
- a review of the equitability of access to the airspace, the appropriateness of the airspace classification and the suitability of the existing services and facilities provided by Airservices Australia.

As of February 2022 this aeronautical study has not been published.

The proposal for the introduction of an SFIS on the Mangalore CTAF is currently on hold pending completion of the OAR review. However, a dedicated controller is providing safety alerting on the Mangalore CTAF in the interim period. Communications on the CTAF are recorded by Airservices when the safety alerting service is operational. A further consultation has been raised by Airservices to lower the base of Class E airspace around Mangalore Airport. As of February 2022 that proposal was in review by Airservices following an industry consultation period.

In December 2021, the Department of Infrastructure announced a $30 million fund to provide rebates to general aviation aircraft operators to fund up to $5,000 or 50% of the cost of installing ADS-B transponder technology into their aircraft.

Safety message

While this accident involved aircraft operating under the IFR, irrespective of whether operating under the instrument or visual flight rules, pilots are responsible for separation from other aircraft in non-controlled airspace.

As such, if made aware of traffic, either via advice from air traffic control (ATC), a received broadcast or any other means it is vitally important that the traffic is risk assessed and, if necessary, a plan established to assure separation. The following separation methods can be useful in maintaining a safe operating distance between aircraft:

- different operating altitudes
- ground feature reference (e.g. townships, lakes or linear features – rivers, roads)
- navigation or avionics reference (e.g. radial or GPS distance)
- ‘clock code’ reference – useful to assist aircraft sighting.

The ATSB also strongly encourages the fitment of ADS-B transmitting, receiving and display devices as they significantly assist the identification and avoidance of conflicting traffic. The continuous positional information that ADS-B provides can highlight a developing situation many minutes before it becomes hazardous – a significant improvement on both point-in-time radio traffic advice and ‘see-and-avoid’. The ATSB also notes that ADS-B receivers, suitable for use on aircraft operating under both the instrument or visual flight rules, are currently available within Australia at low cost and can be used in aircraft without any additional regulatory approval or expense.

It is also important to recognise however that ADS-B cannot be relied upon to display all nearby traffic so effective use of radio remains a primary defence in avoiding mid-air collisions. In that context pilots need to make all required broadcasts detailed in the Aeronautical Information Publication, even if there is no known traffic, and respond to broadcasts if a potential traffic conflict is identified.

The ATSB publication A pilot’s guide to staying safe in the vicinity of non-towered aerodromes highlights some of the known challenges presented to pilots operating around these airfields.

Finally, in line with the key objective of ATC being the prevention of collisions, controllers should advise pilots if they become aware of a developing traffic conflict rather than assume that the pilots are already aware of it.

Contents

The occurrence

On 19 February 2020, at about 1055 Eastern Daylight-saving Time[1], a Beech Travel Air D95A aircraft registered VH-AEM (AEM), departed Tyabb Airport, Victoria for an Instrument Flight Rules (IFR)[2] training flight to Shepparton via Mangalore, and return to Tyabb. A student pilot (the student) and an instructor (the instructor) were on board. The pilots were planning to conduct a practice VOR[3] approach to Mangalore Airport as part of the student's training towards the issue of an instrument rating. AEM was estimated to arrive overhead Mangalore Airport at 1126.

At around the same time, a pilot (the pilot under examination) and flight examiner (the examiner) were at Mangalore Airport, Victoria, preparing for an instrument rating flight test in a Piper PA44-180 Seminole, registered VH-JQF (JQF).

At 1111, the pilot under examination, seated in the left seat of JQF, contacted the Melbourne Centre air traffic controller responsible for the surrounding Class G non-controlled airspace, to advise that the aircraft was taxiing for a departure from Mangalore Airport. The pilot had submitted a flight plan for a round-trip IFR flight via Essendon and Shepparton. At this time, the Mangalore automatic weather station recorded cloud as broken[4], with a base of about 3,200 ft above mean sea level (AMSL).

After departing Tyabb, the crew of AEM climbed the aircraft to 6,000 ft and tracked north through the Melbourne Class C controlled airspace, before being instructed to contact Melbourne Centre. The student pilot first made contact with the Melbourne Centre controller at 1117:42 (Figure 1). They were informed there was no IFR traffic for the descent to Mangalore Airport. At the time the student pilot in AEM acknowledged this information, JQF had not appeared on the controller's surveillance display. At 1120:07 the controller passed traffic information to the pilots of AEM that JQF was shortly to depart Mangalore airport heading to the south.

Surveillance data for JQF first appeared on the controller's display at 1120:31, indicating JQF was airborne. At 1122:19, the pilot under examination in JQF made a departure call to the Melbourne Centre controller and provided information that the aircraft was passing 2,700 ft on climb to 7,000 ft and tracking to waypoint LACEY. The controller identified the aircraft on their display and replied with the area QNH[5]. At 1122:44 the controller provided the pilots in JQF with the following traffic information:

> 6 [nautical] miles in your 12 o'clock is alpha echo mike, a King Air. They are inbound to Mangalore for airwork. Passing 5,000 [ft] on descent to not above 4,000 [ft].

At 1122:49, five seconds after the controller passed this traffic information to the pilots of JQF, an aural and visual short-term conflict alert (STCA)[6] was provided to the controller. The alert indicated that the two aircraft were to come within 4.8 NM lateral and 600 ft vertical proximity in

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1 Eastern Daylight-saving Time (EDT): Coordinated Universal Time (UTC) +11 hours

2 Instrument flight rules (IFR): a set of regulations that permit a pilot to operate an aircraft in instrument meteorological conditions (IMC), which have much lower weather minimums than visual flight rules (VFR). Procedures and training are significantly more complex as a pilot must demonstrate competency in IMC conditions while controlling the aircraft solely by reference to instruments. IFR-capable aircraft have greater equipment and maintenance requirements.

3 VHF Omni-direction Radio Range (VOR): A VHF radio navigational system which provides continuous indication of bearing from the selected VOR ground station.

4 Cloud cover: in aviation, cloud cover is reporting using words that denote the extent of the cover – 'scattered' indicates the cloud is covering between and quarter and a half of the sky, 'broken' indicates that more than half to almost all of the sky is covered, and 'overcast' indicates that all the sky is covered.

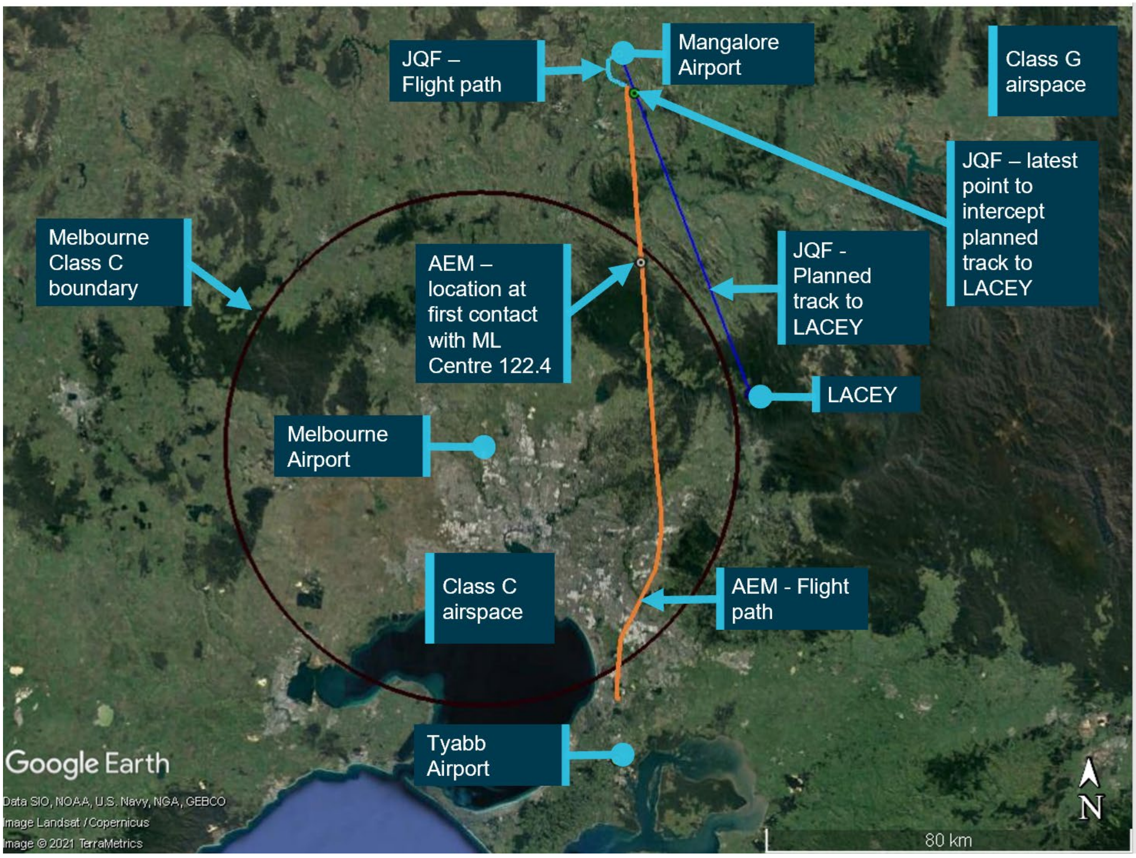
5 QNH: the altimeter barometric pressure subscale setting used to indicate the height above mean sea level.

6 Short Term Conflict Alert (STCA) – a tool intended to assist the controller in preventing a collision between aircraft by generating timely alerts of a potential, or actual, infringement of separation minima. See also the section titled *Short term conflict alert*.

the next 60-90 seconds. Based on the predicted velocity vectors[7] presented on the radar display for the two aircraft, the controller assessed that the aircraft would pass each other, with JQF passing behind AEM, then acknowledged the STCA. At 1123:00 JQF acknowledged the traffic information. By this time, JQF was climbing through 3,250 ft, had a ground speed of 81 kt and had commenced a turn to intercept their planned outbound track from Mangalore Airport to LACEY (Figure 2). At the same time AEM had a ground speed of 187 kt and was descending through 4,918 ft on a track of 354º. At this point, there was 5.4 NM horizontally and about 1,675 ft vertically between the aircraft.

Under IFR operational requirements, the pilots in JQF were required to intercept their outbound track (in this case the direct track between Mangalore Airport and LACEY) within 5 NM of the airfield, and manoeuvre to ensure terrain clearance until above the minimum sector altitude of 3,400 ft within 10 NM of the airfield. Terrain clearance was also assured above 3,900 ft within 25 NM of the airfield.

Figure 1: Flight paths for AEM and JQF, and airspace around Mangalore, including Melbourne Class C airspace and waypoint LACEY



Source: Google Earth and Airservices, annotated by the ATSB

7 Velocity vector: a line that extends from the surveillance track symbol to the estimated future position of the track (computed according to the track's current ground speed) at some selected time interval into the future. Velocity vectors are based on a present track and do not account for a future variations in tracking. The velocity vector is punctuated with dots to show the tracks estimated progress along the vector at regular intervals of time. The direction of the vector indicates the track heading, while the length of the vector gives an indirect indication of the track speed. See the section titled *Controller display* for further information.

In addition to AEM and JQF, there were six other aircraft either taxiing on the ground at Mangalore Airport, operating in the circuit area, or in the local area monitoring the Mangalore common traffic advisory frequency (CTAF).[8] Multiple pilots recalled each of the aircraft communicating separately on the CTAF, with one of the crew of JQF making a, rolling and circuit departure broadcast and a pilot from AEM making an inbound broadcast. However, none of the pilots in the CTAF area recalled any radio communications to arrange separation between AEM and JQF.

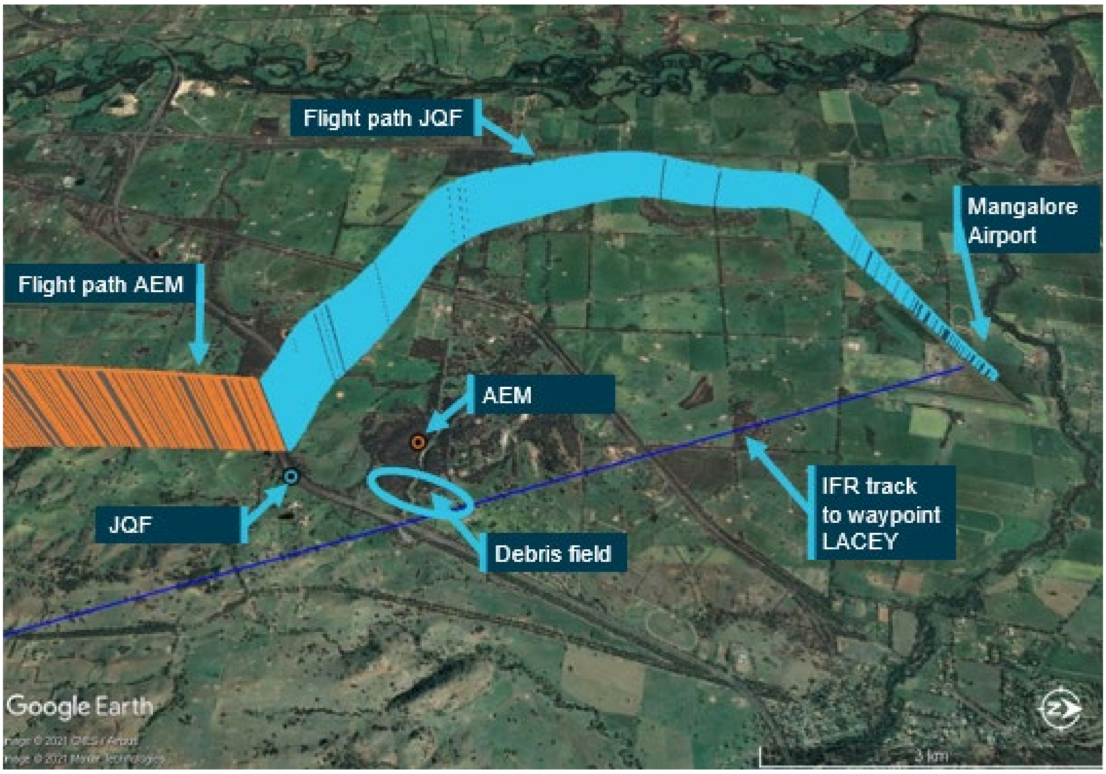
At 1123:51, another STCA appeared on the controller's screen for the two aircraft. The controller acknowledged the STCA at 1124:09, whilst providing traffic information to another aircraft. At the time of the STCA activation, the velocity vector of JQF crossed the velocity vector of AEM, with JQF predicted to pass closely behind AEM. However, the controller's display showed there was 500 ft vertical separation between the aircraft.

At 1124:20 the aircraft collided. Following the collision, the ATC radar display reverted from a presentation of the track of each aircraft based on surveillance data to the flight planned tracks. The controller attempted to contact each aircraft numerous times, before declaring a distress phase for both aircraft.

The collision occurred about 4 NM (7.5 km) south of Mangalore Airport[9] at around 4,100 ft. There were no witnesses to the collision. However, the pilot of a helicopter operating to the south of the collision point reported seeing one aircraft (AEM) descending rapidly, with the other aircraft (JQF) descending more slowly while spinning. Two other witnesses, one, a pilot located on the airfield, and a second closer witness, similarly reported seeing JQF spinning toward the ground.

The two aircraft impacted the ground about 1.3 km apart (Figure 2). Some lighter debris from each aircraft was located at a third location downwind from the collision point. All four pilots were fatally injured in the accident, and both aircraft were destroyed.

Figure 2: Flight path of AEM and JQF, and location of the ground impact of both aircraft



Source: Google Earth and Airservices, annotated by the ATSB

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8 Common Traffic Advisory Frequency (CTAF): A designated frequency on which pilots make positional broadcasts when operating in the vicinity of a non-controlled aerodrome or within a Broadcast Area.

9 Distances are taken from the Mangalore Aerodrome Reference Point (S36° 53.18' E145° 11.03').

Context

Personnel information

All four pilots and the air traffic controller held the required licences and medical approvals. It was considered unlikely that fatigue affected the performance of any of the involved pilots, due to the time of the accident, and their previous work and rest times. Workload and fatigue assessments for the controller are detailed in a separate section below.

VH-AEM instructor

Qualifications and experience

The instructor onboard VH-AEM (AEM) held an Air Transport Pilot Licence (Aeroplane) (ATPL(A)) issued on 29 January 2004, and a Commercial Pilot Licence (Aeroplane) (CPL(A)) issued on 13 October 1993. The instructor also held a Grade 1 flight instructor rating with endorsements for multi-engine class rating[10] training and instrument rating training. The instructor had an English language proficiency of level 6[11].

The instructor's instrument rating and multi-engine aircraft rating were valid until 29 February 2020, and their flight instructor rating was valid until 30 June 2020. The instructor had previously held an examiner rating covering private pilot licence and night visual flight rules testing endorsements, and English language proficiency assessments.

The instructor's logbook showed a total flying experience of 5,907.2 hours to the last recorded flight on 14 February 2020. In the previous 90 days, the instructor had flown 29.3 hours of which 7.6 hours were in the Beech D95A Travel Air (Travel Air) aircraft type. In the previous 30 days the instructor had flown 25.1 hours total, 5.4 of which were on type.

The instructor had been the operator's Chief Pilot since March 2019, and the Head of Operations since April 2019.

Medical information

The instructor held a class 1 aviation medical certificate valid until May 2020, with a restriction that it could not be used for ATPL operations. The instructor had a mild colour vision deficiency which had been assessed by specialists as 'extremely mild' and had been declared to the Civil Aviation Safety Authority (CASA).

There were no restrictions preventing the instructor from undertaking commercial operations including flight instruction. Additionally, the instructor was not required to wear any vision correction in flight.

VH-AEM student

Qualifications and experience

The instrument rating student in AEM held a CPL(A) issued on 30 April 2013. The student had also previously held a Grade 3 flight instructor rating permitting single engine aircraft, night VFR and design feature training. The student also held activity endorsements for formation flight, aerobatics and spinning. The student held a level 6 English language proficiency assessment.

The student's logbook showed a total flying experience of 1,103.1 hours to the last recorded flight on 17 February 2020. The student's total flying experience on the Travel Air was 6.6 hours. In the

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10 Multi-engine class rating: An aircraft class rating is a flight crew qualification that authorises the holder to operate aircraft that fit the description of the class rating and are not designated as a type-rated aircraft. See the section titled *Pilot licencing*.

11 English language assessment: a measure of someone's ability to communicate in English using an aviation-relevant assessment process. Level 6 indicates expert level and does not expire.

previous 90 days, the student had flown a total of 60.4 hours, including the 6.6 hours on the Travel Air; and in the last 30 days had flown 30.3 hours with 2.2 of those in the Travel Air.

Medical information

The student held a Class 1 aviation medical certificate valid until 2 September 2020. There were no restrictions on their medical certificate.

Instrument rating training

An instrument rating is an operational rating permitting a pilot to fly under the IFR.

The student passed their instrument rating theory examination on 2 October 2019. Logbook records indicate that the pilot first completed 1.1 hours in the simulator for 'NDB and instrument flying' in June 2019. This was completed with another instructor.

Records indicate that the Travel Air instructor and the student began flying together in October 2019 for the purposes of completing the instrument rating. Table 1 identifies the flights logged in the student's logbook, conducted as flight training toward the instrument rating with multi-engine aeroplane instrument endorsement. The first three flights were conducted as day VFR flights in the Travel Air, conducting elements of handling required for the multi-engine endorsement (see the section titled *Pilot Licencing*).

Table 1: Flights completed in preparation for instrument rating

Date	Aircraft	Duration (Hours)	Details
14 October 2019	VH-AEM	0.9 (VFR)	General handling, stalls and circuits
16 October 2019	VH-AEM	1.1 (VFR)	Circuits, go arounds
21 October 2019	VH-AEM	2.4 (VFR)	Tyabb – LaTrobe Valley – Asymmetric engine operation and engine failure after take-off - Tyabb
28 October 2019	Simulator	1.7 (IFR)	Sector entry and holding / basic instrument flying
28 October 2019	Simulator	1.0 (IFR)	Holding with winds
18 November 2019	Simulator	1.0 (IFR)	ILS at Essendon, RNAV and hold at Moorabbin
20 January 2020	Simulator	2.1 (IFR)	Holding, cross wind, RNAV Mangalore and Yarram, VOR Approach
23 January 2020	Simulator	2.0 (IFR)	Moorabbin, Yarram – Holding and RNAV, Essendon ILS
28 January 2020	VH-AEM	2.2 (IFR)	Tyabb – Yarram – LaTrobe Valley – MOZZA[2] – MONTY – Essendon ILS
1 February 2020	Simulator	1.2 (IFR)	Moorabbin – Mangalore – VOR approach

[1] ILS, RNAV and VOR are types of instrument approaches.
[2] MOZZA and MONTY are IFR waypoints. See the section titled *Operational information*.

VH-JQF examiner

Qualifications and experience

The examiner on board VH-JQF (JQF) held an ATPL(A) that was issued on 17 July 1978. They held a flight examiner rating permitting examination of a variety of operational ratings, including an instrument rating and multi-engine aeroplane class rating. The examiner had a level 6 English language proficiency.

The operator's records indicate the examiner received a briefing on relevant operational policies in August 2018. However, as per the regulations, the examination flight was conducted as a private flight rather than a commercial operation.

The examiner successfully completed an instrument rating proficiency check in a Seminole on 17 February 2020, two days before the accident flight. The examiner's instrument rating and multi-engine class rating were valid until 28 February 2021. The examiner's grade 1 flight instructor rating was valid until 31 December 2021.

The examiner's flight examiner rating had exceeded the renewal date, however, operation as an examiner was still permitted under CASA EX70/18, an exemption issued by CASA to extend the requirement to conduct a proficiency check until March 2020. This exemption was issued to assist with the transition of examiners from the Authorised Testing Officer delegations to the Civil Aviation Safety Regulations Part 61[12] Flight Examiner ratings.

A review of the examiner's logbook showed a total flying experience of about 21,600 hours. CASA records indicate that the examiner conducted 194 flight tests in the 2 years prior to the accident, of which 34 were for the initial issue of an instrument rating.

Medical information

The examiner held a class 2 aviation medical certificate that was valid until 15 October 2020. There were two restrictions placed on the examiners medical certificate:

- Distance correction was to be worn while exercising the privileges of this licence.
- Reading correction was to be available while exercising the privileges of this licence.

The available evidence indicates that these restrictions were being complied with at the time of the accident.

VH-JQF pilot under examination

Qualifications and experience

The pilot under examination had been enrolled in a diploma course with the operator since February 2017, and although having completed most of the flying program from Moorabbin Airport they were also familiar with operating to and from Mangalore Airport. The pilot under examination held a CPL that was issued on 24 June 2019. The final component of their training was the instrument rating and multi-engine class rating, being tested during the accident flight. The pilot had a level 6 English language proficiency.

The pilot's logbook showed a total flying experience of 244.9 hours to the last recorded flight on 17 February 2020. The pilot's total flying experience in the Seminole was 22.2 hours. In the previous 90 days, the pilot had completed 20.4 hours total flying (all in the Seminole), and in the last 30 days had completed 4.8 hours flying.

Medical information

The pilot's Class 1 aviation medical certificate was renewed 3 days prior to the accident and was valid until 12 March 2021. There were no restrictions placed on their medical certificate.

Instrument rating training

The purpose of the accident flight was examination for an instrument rating, a multi-engine aeroplane instrument endorsement and a multi-engine aeroplane class rating. The pilot under examination had passed the theory component for the instrument rating on 11 November 2019.

[12] Civil Aviation Safety Regulations (CASR) 1998 Part 61 prescribes the requirements and standards for the issue of flight crew licences, ratings and other authorisations, including those issued to pilots and flight engineers. It also includes the privileges, limitations and conditions on such authorisations, and rules for the logging of flight time.

Records indicate that the pilot began training for the multi-engine class rating and the instrument rating in August 2019. During this training, the pilot logged:

- Day multi-engine aircraft flight: 32.0 hours
- Night multi-engine aircraft flight: 7.2 hours
- In-flight instrument flight time: 17.2 hours (logged during the 39.2 day and night multi-engine aircraft flight hours)
- Simulator time: 20.4 hours

All training was completed with one instructor, and all flying was conducted in a Seminole. Documentation recommending the pilot for the flight examination was completed by this instructor after a final practice flight on 17 February 2020, which included flying to Mangalore Airport.

Air traffic controller

Qualifications and experience

The controller had worked for Airservices Australia (Airservices) since 1989. The controller was issued with ratings for area procedural control and area radar control in 1996; and was issued with an endorsement for the sector being controlled on the day (see the section titled *Airspace*) in January 2012. The controller held a level 6 English language proficiency.

The controller held a Class 3 medical, appropriate for air traffic controllers, which was valid until 6 October 2021, and required the controller to have reading correction available.

The most recent training completed by the controller prior to the accident was compromised separation refresher training on 2 October 2019, and effective scanning training on 26 February 2019.

Roster and workload

The controller reported that they did not feel fatigued prior to, or at the time of the accident. The controller noted that although some of the roster patterns worked could be fatiguing, controllers found ways to manage this. A review completed by Airservices did not identify any fatigue related- issues with the controller’s roster.

While the roster had a mix of morning, afternoon and night shifts during February, in the 3 days prior to the accident the controller had completed the following roster:

- Sunday 16 February: day off
- Monday 17 February: 1400 - 2200
- Tuesday 18 February: 1400 - 2200
- Wednesday 19 February: 1100 start

The controller recalled being asleep by midnight after the shift on Tuesday 18 February and waking to an alarm at 0800 on Wednesday morning. The controller arrived at work about 15 minutes early, to prepare for the day.

The controller described the workload on the day as having ‘a bit going on’, but not busy. It was further stated that there were no particular pressures on the day of the accident.

Medical and pathological information

Given the nature of the mid-air and ground collisions, the accident was not survivable for any of the four pilots.

The autopsy of the examiner in JQF identified a level of ischaemic heart disease capable of causing death in isolation from other factors, but there was no evidence of an acute cardiac event having occurred at the time of the incident.

No other significant medical issues were identified in any of the remaining pilots. Further, the toxicology results did not identify any substance that could have impaired the pilots' performance or that were not noted in their aviation medical records.

Aircraft information

Both aircraft met the equipment requirements for flight under the IFR, detailed in *Civil Aviation Order 20.18* including the carriage of Automatic Dependent Surveillance – Broadcast (ADS-B)[13] equipment (see the section titled *Automatic dependent surveillance* broadcast).

VH-AEM

The Beech D95A Travel Air is a four to six seat, low-wing, retractable-tricycle-undercarriage aircraft fitted with two 180 horsepower Textron Lycoming IO-360-B1B reciprocating engines driving constant-speed, two-bladed propellers.

AEM (Figure 3) was manufactured in the United States in 1966 with serial number TD 682. It was first registered in Australia in 1967, and prior to the departure from Tyabb, the aircraft had accumulated 7,400.3 hours in service.

Figure 3: Beech Travel Air VH-AEM

Source: Aircraft operator, annotated by the ATSB.

AEM had a current Certificate of Registration, Certificate of Airworthiness and maintenance release. The last maintenance conducted on the aircraft was a calibration of the aircraft's altimeters, air speed indicators, compass, pitot-static system and fuel quantity system, conducted on 17 January 2020.

The aircraft was certified for IFR and charter operations and was equipped with dual controls for the student and instructor. The aircraft was also equipped with a Garmin GNS530 radio communication and GNSS navigation system, together with a second communication radio. The aircraft was also fitted with a Garmin GTX335 ADS-B OUT transponder. AEM did not have any ADS-B receiving equipment.

One notable modification to the aircraft was the replacement of the original two frame windscreen with a single pane 'speed-slope' windscreen. The exact date of replacement was unknown, however this was a common modification to Travel Air aircraft. The speed-slope screen is a component of later-model Travel Air aircraft and Beech Baron aircraft.

The modification involved removal of the centre spine of the original screen, with no further modifications to the fuselage roof area or side frames. The lower section of the speed-slope

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13 Automatic Dependent Surveillance Broadcast (ADS-B): a means by which aircraft, aerodrome vehicles and other objects can automatically transmit or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via data link.

screen protruded approximately 75-100 mm further towards the aircraft nose than the original windscreen. A larger glareshield was also fitted to the aircraft to fill the space between the instrument panel and the new windscreen.

A review of the previous two aircraft maintenance logbooks for AEM showed that the speed-slope screen was last replaced on 5 August 2011, and that the pilot's side window had been replaced on 25 December 2014.

VH-JQF

The Piper PA-44 Seminole is a four-seat, low-wing, twin-engine light aircraft. It is powered by two 180 horsepower Textron Lycoming O-360-E1A6D reciprocating piston engines. JQF was fitted with three-blade, constant-speed and full-feathering aluminium propellers. The Seminole is equipped with hydraulically-operated, retractable, tricycle landing gear. JQF (Figure 4) was manufactured in the United States in 1979 with serial number 44-7995291. It was first registered in Australia in 1990. The aircraft was owned by the operator. Prior to the accident flight, the aircraft had accumulated a total flight time of 11,190.6 hours.

Figure 4: Piper Seminole VH-JQF

Source: Aircraft operator, annotated by the ATSB.

JQF had a current Certificate of Registration, Certificate of Airworthiness and maintenance release. The maintenance release was issued on 12 February 2020, and the aircraft had completed 18.0 hours flying since that time.

The aircraft was certified for IFR and private/airwork operations. It was equipped with dual controls for the student and instructor. The aircraft was also equipped with a Garmin GNS430 radio communication and GNSS navigation system and a second communication radio. The aircraft was fitted with an Appaero Stratus Mode-S transponder unit, which had ADS-B OUT transmit capability only.

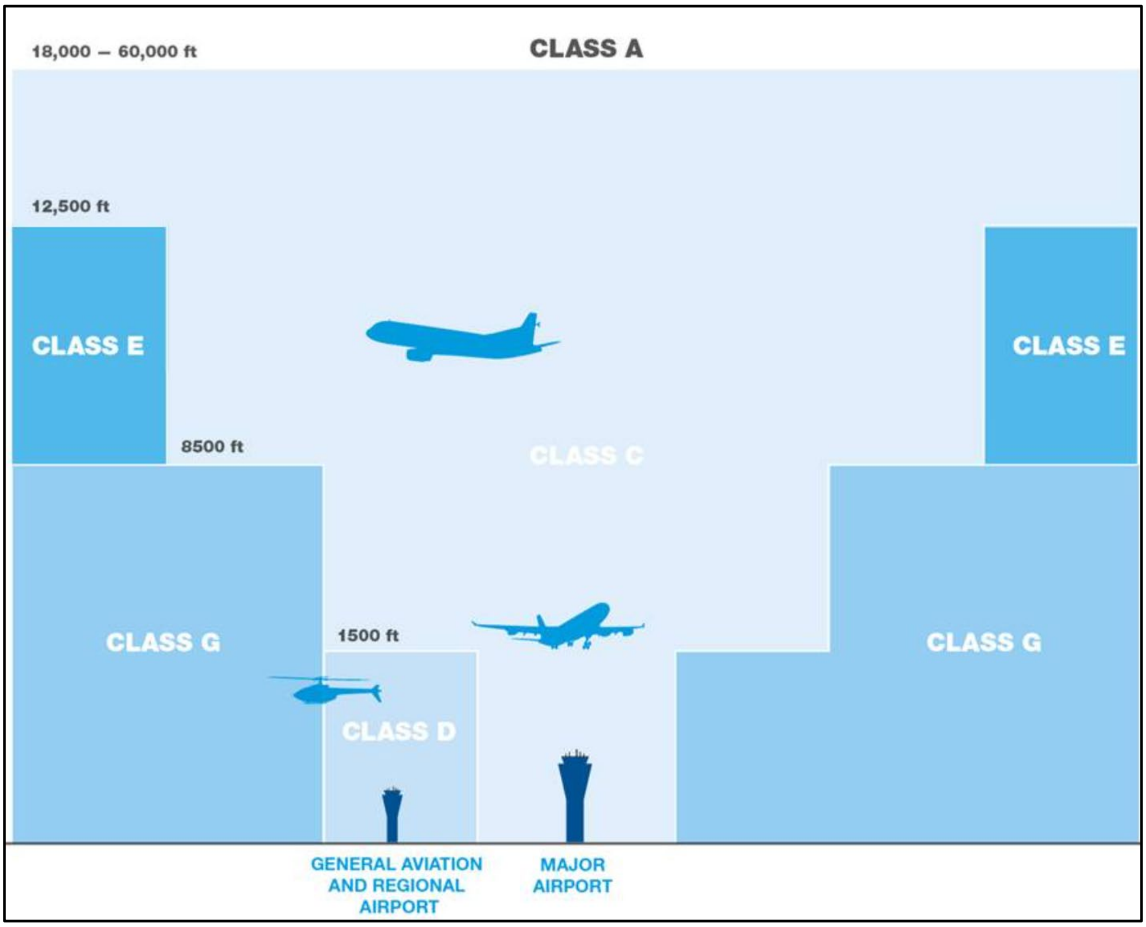
Operational information

Airspace

Overview

Airspace in Australia is separated into different classes that may be either controlled (Class A, Class C, Class D, Class E) or non-controlled (Class G) (Figure 5). Different services are offered to aircraft that operate in these airspace classes, based on the flight rules the aircraft is operating under (see the section titled *Air traffic services*).

Figure 5: Australian airspace structure



Source: Airservices

Common traffic advisory frequency

Mangalore Airport is a non-controlled airport that operates on a common traffic advisory frequency (CTAF). This frequency is shared with four other airfields in the local area – Locksley Field, Nagambie-Wirrate, Wahring Field and Puckapunyal (Figure 6).

The precise boundaries of a CTAF are not defined, however, the Aeronautical Information Publication (AIP[14]) stated that:

> An aircraft is in the vicinity of a non-controlled aerodrome if it is within a horizontal distance of 10 [nautical] miles; and within a height above the aerodrome reference point that could result in conflict with the operations at the aerodrome.

Mangalore Airport is located 4 NM north of an 8,500 ft Class C control step. The accident took place almost directly underneath the 8,500 ft step boundary (Figure 6). Class G non-controlled airspace surrounds Mangalore Airport up to 8,500 ft; with Class E controlled airspace from 8,500 ft to flight level[15] 125 (FL125) and Class C controlled airspace from FL125 to FL180. Class A controlled airspace was in place above FL180.

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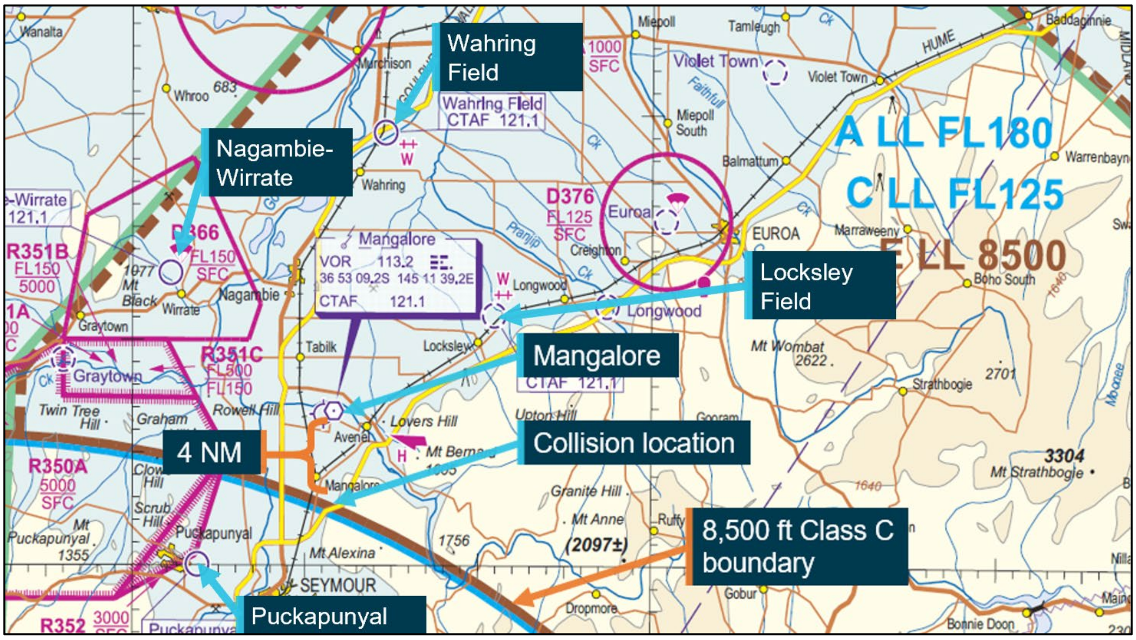
14 All regulation references refer to the version current at the time of the accident. For the AIP, this is the version current from 7 November 2019.

15 Flight level: at altitudes above 10,000 ft in Australia, an aircraft's altitude at standard air pressure is referred to as a flight level (FL). FL 125 equates to 12,500 ft. FL 180 equates to 18,000 ft.

Figure 6: Airspace surrounding Mangalore Airport



Source: Airservices, annotated by the ATSB.

Class G airspace

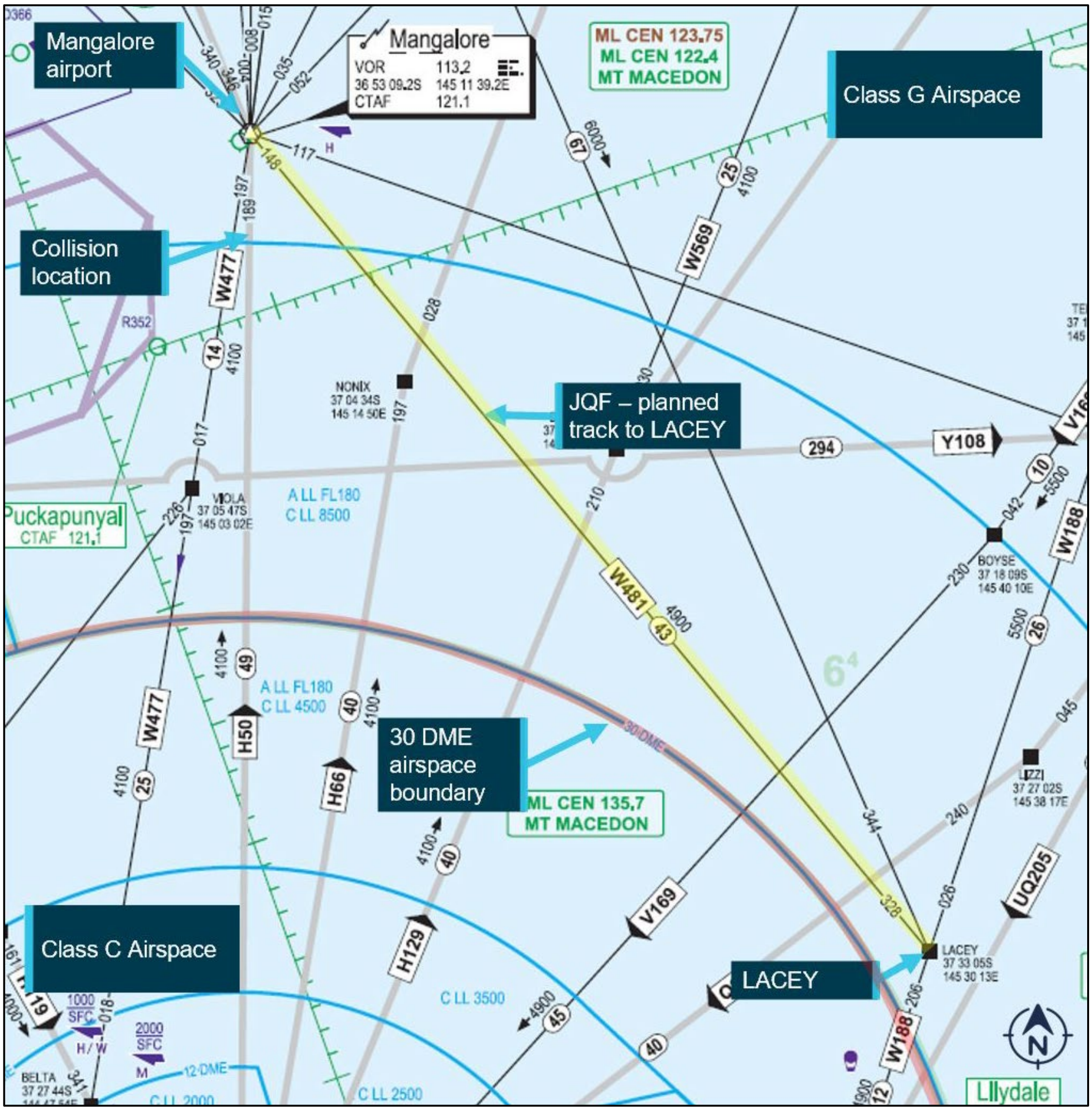
Class G airspace has been operational in Australia since 1995. In Class G airspace, air traffic controllers provide a traffic information service to IFR aircraft about conflicting IFR and observed VFR flights (see the section titled *Flight Information Service*). Controllers have offered a similar ‘flight service’ to IFR aircraft operating in non-controlled airspace since 1963.

AEM was transferred from one Melbourne Centre controller to another Melbourne Centre controller, just prior to the 30 DME[16] control boundary (Figure 7), where the lower level of Class C airspace increased from 4,500 ft to 8,500 ft.

The pilots of AEM first made contact with the Melbourne Centre controller at 1117:42, and they entered the airspace around 1118:22. They were not on the Melbourne Centre frequency at 1111 when the pilot of JQF made their taxi call to the Melbourne Centre controller.

16 Distance Measuring Equipment (DME): Equipment which measures in nautical miles, the slant range of an aircraft from the selected DME ground station. A DME distance is the slant range from a DME signal to the receiving antenna. The 30 DME control boundary is measured from Melbourne Airport.

Figure 7: Airspace around Mangalore Airport and the outbound IFR track to LACEY



Source: Airservices, annotated by the ATSB

Rules of the air

While both aircraft were operating in the same airspace under the IFR and were in contact with the Melbourne Centre controller, due to the airspace being class G non-controlled airspace, the controller was providing a flight information service only to these aircraft, rather than a traffic control service with positive separation (see the section titled *Flight information service*). This meant that, as with VFR operations in non-controlled airspace, the pilots were responsible for ensuring they maintained sufficient separation.

The *Civil Aviation Regulations 1988 161 through 166* sets out a number of associated regulations detailing pilot responsibilities in relation to rules for the prevention of a collision, operating near other aircraft, right of way and operating in non-controlled airspace.

With regard to the responsibility of pilots to communicate on VHF radio, *Civil Aviation Regulation 166C – Responsibility for broadcasting on VHF radio* states

(1) If:

a. An aircraft is operating on the manoeuvring area of, or in the vicinity of, a non-controlled aerodrome; and

b. The aircraft is carrying a serviceable aircraft VHF radio; and

c. The pilot in command of the aircraft holds a radiotelephone qualification;

The pilot is responsible for making a broadcast on the VHF frequency in use for the aerodrome in accordance with subregulation (2)

(2) The pilot must make a broadcast that includes the following information whenever it is reasonably necessary to do so to avoid a collision, or the risk of a collision, with another aircraft:

a. The name of the aerodrome;

b. The aircraft's type and call sign;

c. The position of the aircraft and the pilot's intentions.

The AIP defines a broadcast as: A transmission of information relating to air navigation for which an acknowledgement is not expected.

The AIP further clarified statements about broadcasts and collision avoidance in GEN 3.3 paragraph 7.5.1 Acknowledgement of broadcasts:

> Broadcasts should not be acknowledged unless a potential collision risk exists

Flight plans

AEM

The student pilot of AEM submitted a flight plan to Airservices at 1041 on the morning of the flight. The flight plan details were to

- depart Tyabb Airport at 1055
- fly direct to Mangalore Airport and conduct the VOR hold and approach
- depart to Shepparton Airport for the Area Navigation (RNAV) Global Navigation Satellite System (GNSS)[17] approach
- return via Mangalore and LACEY to Moorabbin for the RNAV GNSS approach before returning to Tyabb.

A witness from Tyabb reported that the instructor and instrument rating student had tried to book slots to conduct instrument approaches at airports in the Melbourne control zone but were unable to secure any on the morning of the flight[18]. They were also unable to operate at East Sale due to military training. Therefore, it was decided to fly to Mangalore and Shepparton.

The aircraft proceeded as per the flight plan. The pilots were transferred to the Melbourne Centre controller just prior to the airspace boundary and entered the Class G airspace while maintaining 6,000 ft about 24 NM south of Mangalore Airport. About 90 seconds later, when the aircraft was about 18 NM from Mangalore Airport, the student pilot contacted Melbourne Centre to report their departure from 6,000 ft for airwork at Mangalore not above 4,000 ft (operations between ground level and 4,000 ft).

The planned instrument approach was the VOR approach to runway 23 (see the section titled *Mangalore VOR*). The approach required them to pass overhead the VOR not below 3,900 ft before beginning the outbound leg of the approach, and descending to no lower than 1,800 ft. There were no reported issues with the serviceability of the VOR at the time of the occurrence.

JQF

The pilot under examination submitted a flight plan at 0949. The flight plan detailed:

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17 Area Navigation (RNAV) Global Navigation Satellite System (GNSS) approach: A type of non-precision instrument approach procedure.

18 Airservices run a booking system for conducting practice instrument approaches at airports within controlled airspace. In Victoria this booking system includes instrument approaches at Avalon, Essendon and Moorabbin airports.

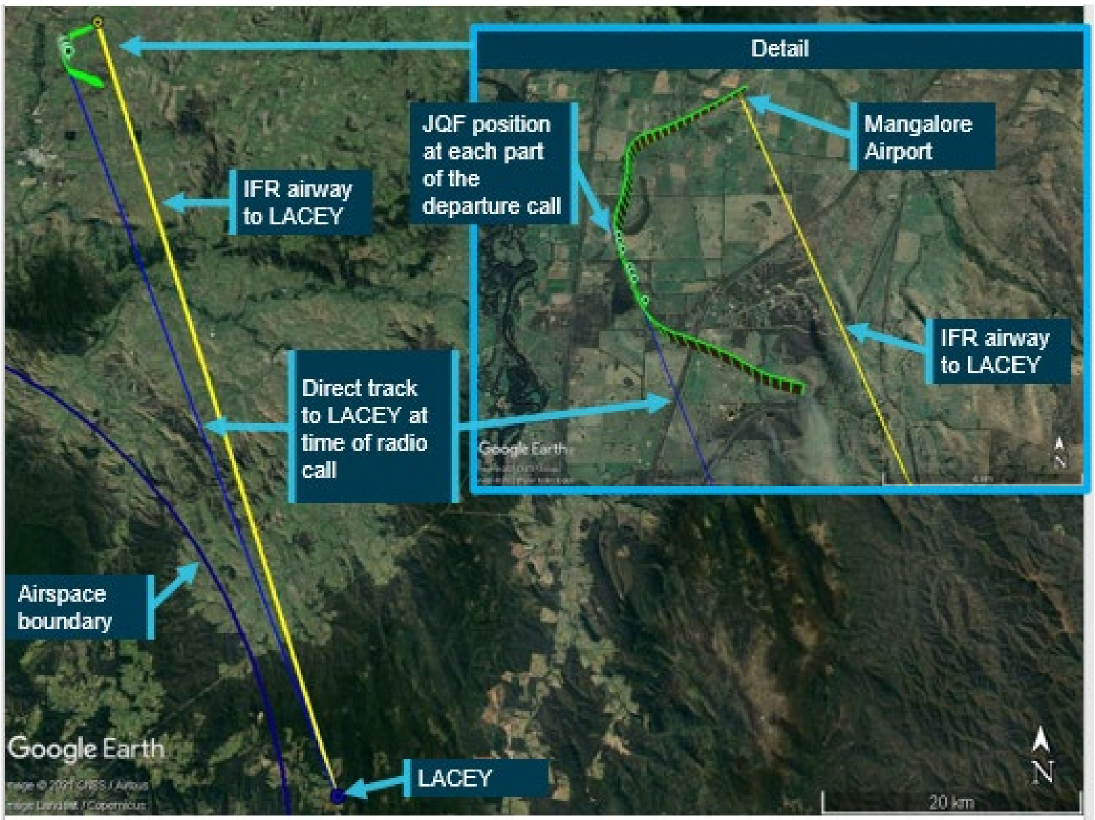
- an 1100 departure from Mangalore Airport and climb to 7,000 ft while tracking to LACEY
- conduct of an ILS[19] approach at Essendon Airport
- a return to Mangalore for the VOR approach
- conduct of an NDB[20] approach at Shepparton Airport before returning to Mangalore for an RNAV approach.

The flight plan submitted to Airservices did not specify the route planned to LACEY, other than Mangalore Airport direct to LACEY. However, a copy of a handwritten flight plan indicated the intention to track from Mangalore to LACEY along the published IFR route W481 (Figure 7).

JQF commenced the take-off roll from runway 23 at Mangalore just prior to 1120. The aircraft initially departed in an extended upwind direction, before commencing a series of left turns that resulted in the aircraft tracking towards the planned route to LACEY (Figure 8).

The pilot under examination made a departure call to the Melbourne Centre controller with the first communication commencing at 1122:19. At the time of this call, during which the pilots were provided traffic information about AEM, the track maintained by JQF was direct to LACEY. This may have been intentional, or co-incidental due to the increased workload of the student during the take-off phase and climb phase and managing the radio during the Melbourne Centre call. It was at this time the controller reviewed the velocity vectors that were based on the track of the aircraft not the flight planned track, and assessed that JQF would pass behind AEM (see the section titled *Short term conflict alert*). However, at the end of the radio communication, JQF resumed the turn towards the planned route to LACEY via route W481.

Figure 8: Track of JQF after take-off from Mangalore Airport



Source: Google Earth and Airservices, annotated by the ATSB

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19 Instrument Landing System (ILS): A precision instrument approach system which normally consists of the following electronic components: VHF Localiser, UHF Glideslope, VHF Marker Beacons.

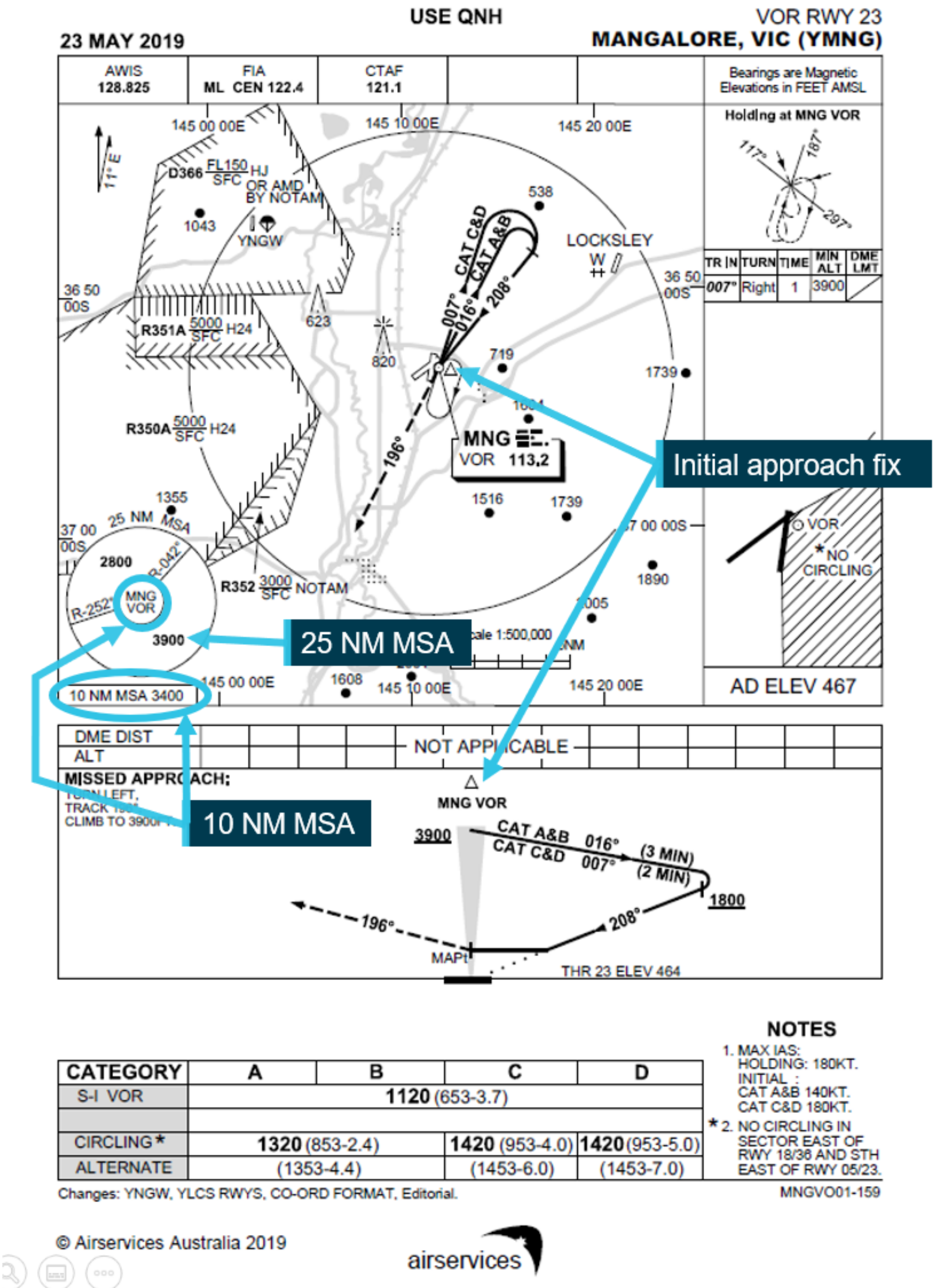
20 Non-Directional Beacon (NDB): A special radio station, the emissions of which are intended to enable a mobile station to determine its radio bearing or direction with reference to that special radio station.

Mangalore VOR

The Mangalore VOR is one of four such navigation aids in Victoria. As part of the 2016 Navigation Rationalisation project, in a move towards using a Global Navigation Satellite System (GNSS), 179 ground-based navigation aids were decommissioned across Australia. Twenty eight of the decommissioned instrument approaches were in Victoria, including five VORs. The Mangalore VOR was maintained as part of the back-up network, along with VORs at Melbourne, Avalon and Mildura airports. Despite fewer available local VORs since the decommission of navaids, IFR traffic numbers using Mangalore Airport have decreased (see the section titled *Aerodrome information).*

Figure 9 details the published VOR instrument approach to Mangalore Airport.

Figure 9: Mangalore Runway 23 VOR approach



Source: Airservices, annotated by the ATSB

Pilot Licencing

Licencing of pilots with operational ratings and endorsements, such as the multi-engine aeroplane class rating and the instrument rating, requires the pilot to demonstrate relevant competencies to a flight examiner. These competencies are set by CASA and mandated under Part 61 of the Civil Aviation Safety Regulations (CASR).

The CASR Part 61 Manual of Standards (MOS) details these competencies both for initial testing and recurrent examination. At all stages of pilot licencing, competence in non-technical skills must be demonstrated by pilots under examination, including

- Maintain effective lookout
- Maintain traffic separation using a systemic visual scan technique at a rate determined by traffic density, visibility and terrain;
- Maintain radio listening watch and interpret transmissions to determine traffic location and intentions;
- Recognise and manage threats

Of the Part 61 MOS competencies outlined for the instrument rating, there were two competencies that were relevant to the departure path flown by the pilot of JQF:

- 2.2 (e) conduct instrument departure to comply with obstacle clearance requirements.
- 4 (w) pilot's responsibility in an IFR visual departure.

If either of these competencies were not demonstrated, then it would be marked as a failure item for the test.

In complying with 2.2(e), the AIP ENR 1.5 stated:

> 4.4 Take-off minima for other IFR aeroplanes
>
> 4.4.3 – It is a condition of the use of the minima in Section 4.4 that the pilot in command of the aeroplane must ensure that:
>
> a. terrain clearance is assured until reaching either an en-route LSALT[21] or departure aerodrome MSA[22]

As identified on the VOR chart (Figure 9), the minimum sector altitude within 10 NM of Mangalore Airport was 3,400 ft, and the minimum sector altitude within 25 NM to the south and south-east of the airport was 3,900 ft. Therefore, the pilot of JQF had to ensure terrain clearance was maintained until the aircraft climbed to 3,400 ft.

In complying with 4(w), AIP ENR 1.1 paragraph 10.6.2 stated:

> The pilot of a departing aircraft is required to establish the aircraft on the outbound track as soon as possible after take-off, and in any case, within 5 nm of the departure aerodrome.

JQF departed from runway 23, and was flight planned on a published IFR route southbound via waypoint LACEY. Figure 10 identifies the latest position at which JQF could have intercepted this outbound track and complied with the requirement to be 'established'.

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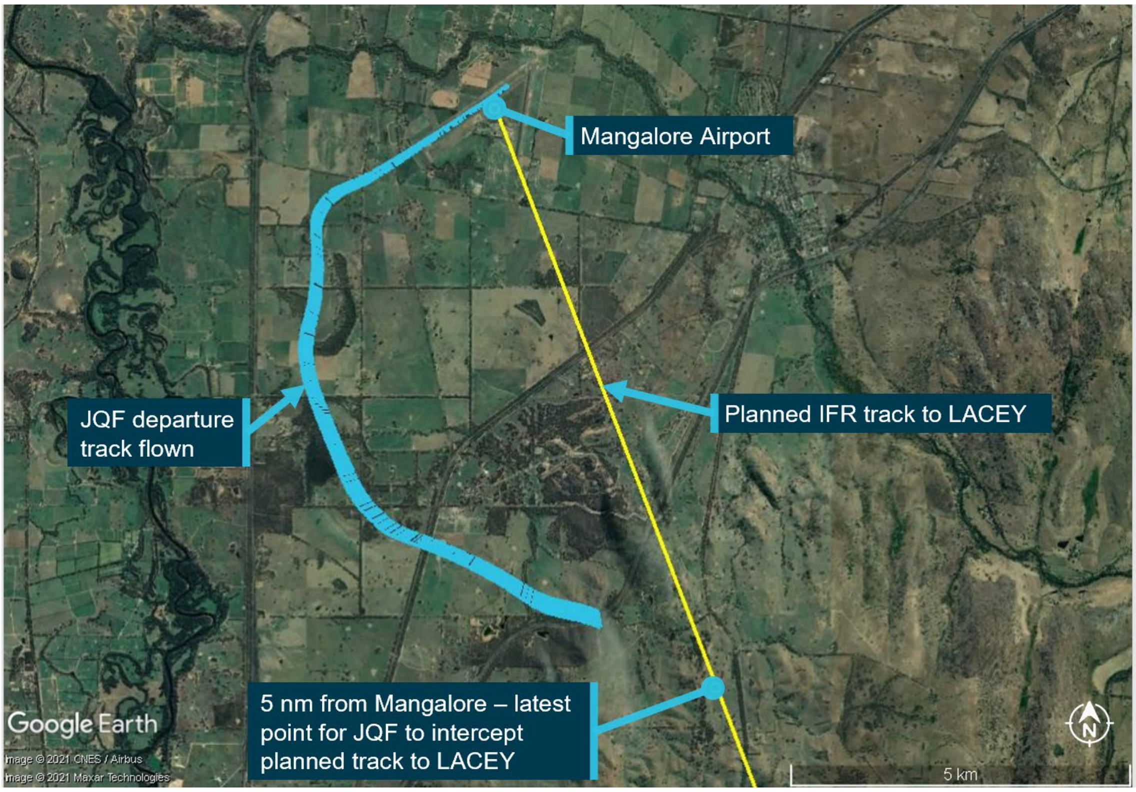
21 Lowest Safe Altitude (LSALT): The lowest altitude which will provide safe terrain clearance at a given place.

22 Minimum sector altitude (MSA): The lowest altitude which may be used which will provide a minimum clearance of 300 m or 1,000 ft above all objects located in an area contained within a sector of a circle of 25 NM or 10 NM radius centred on a significant point, the Aerodrome reference point or the Heliport reference point.

Figure 10: JQF track flown and planned track to LACEY



Source: Google Earth and Airservices Australia, annotated by the ATSB

Another competency for a multi-engine aircraft class rating is the requirement to demonstrate how to safely manage a simulated engine failure. The ATSB considered the possibility that the examiner of JQF had simulated an engine failure for the pilot under examination take-off from Mangalore. However evidence provided by the operator suggested that this would not have been the standard practice of the examiner and the recorded climb performance was indicative of the aircraft climbing at a normal two-engine climb rate.

Neither the student in AEM or the pilot under examination in JQF were likely to have been wearing an IFR 'hood', used to simulate instrument conditions, at the time of the accident. AEM had been in cloud for most of the descent from 6,000 ft and the hood for JQF was found in a basket behind the pilot seats, having not been used for the flight.

Self-separation by radio

As previously detailed, while operating in non-controlled airspace, even under the IFR, pilots remain responsible for ensuring their own separation from other aircraft. While the occupants of the two aircraft were provided with traffic information, where the possibility for traffic conflict occurs, communication between pilots over the radio remains the primary means for ensuring separation.

Interpreting location information heard over the radio into a useful mental model is a practical skill taught to pilots during initial training, and developed with experience. Once a pilot hears where another aircraft is through a radio call, they must:

- process the audio information
- identify where that aircraft is in relation to their own aircraft
- determine where both aircraft are heading
- assess whether there is a potential conflict and, if so, communicate this risk with the other aircraft.

Despite the importance of this skill, there is limited written guidance to pilots on how to communicate and arrange this separation. CASA CAAP 166-2 (2013) is one document that provided the following written guidance to pilots on suggested methods for traffic separation by radio:

> Accurate provision and interpretation of traffic information for the purposes of separation to or from another aircraft is an essential pilot skill. Four commonly used ways of providing and interpreting traffic information by radio communication for the purpose of airborne separation are practised at non-controlled aerodromes. All methods have their advantages depending upon circumstances.
>
> - Separation by 'clock code' – Pilots maintain traffic separation by reference to the central axis and numbers of an analogue clock face. Particular care must be given to identifying which aircraft is the central axis of the clock. *You are at my 2 o'clock and low* has the opposite meaning to I am at your 2 o'clock and low. The weakness of this method of separation is that is requires at least one pilot to have seen, identified and made contact with the other aircraft.
> - Separation by ground reference – Pilots maintain separation by radio by either identifying that each is in different places relative to a ground feature(s), or by agreeing to remain on different sides of a readily identifiable ground feature such as a runway extended centreline, road, town or railway line. The advantage of this method of separation is that it does not required either aircraft to have actually seen each other (although this is desirable). The weakness of this method of separation is that ground features could be misidentified. The uncertainty or confusion can distract from the effort of retaining separation through see-and-avoid.
> - Separation by altitude reference – Pilots maintain separation by radio by identifying that each is at a different altitude or by one aircraft descending/climbing to another level. Provided that both aircraft altimeters are set to the correct subscale reference (QNH) this method should provide separation for both aircraft regardless of visual contact.
> - Separation by navigational or avionic reference – Pilots maintain separation by identifying that each is in a different place relative to a known navigational point or line (radial), or separated by distance from a fixed point (e.g. Global positioning system (GPS) or a radio navigation aid). This method of separation does not require either aircraft to have actually seen each other (although this is desirable). The weakness of this method of separation is that differing avionic equipment or pilot navigational skill can lead to incorrect assumptions being made about the usability of the separation information offered.

Air traffic services

Overview

Airservices is the national air traffic services (ATS) provider for other than military-related airspace within Australia. A number of different services are provided by Airservices based on the airspace classification (Table 2), broadly described as either an air traffic control service, or a flight information service.

Table 2: Services provided to IFR aircraft in Australian Airspace

		CONTROLLED		
		CLASS A	**CLASS C**	**CLASS D**
		Above FL245 outside radar coverage Above FL180 within radar coverage	Terminal areas with ATC services En route between major centres	Regional and some metropolitan CTR and associated low-level CTA steps
IFR	Radio RQ	YES	YES	YES
IFR	Transponder RQ	YES—including ADS-B OUT	YES—including ADS-B OUT	YES—including ADS-B OUT
IFR	SUBJ ATC clearance	YES	YES	YES
IFR	Separation provided	All aircraft	All aircraft	IFR from IFR and Special VFR, (except during a VFR departure, or when conducting VFR climb or descent)
IFR	Service provided	ATC service	ATC service	ATC service for separation from IFR Traffic information about VFR flights (and traffic avoidance advice on request)
IFR	Speed limits	N/A	N/A	250 KIAS max (unless the pilot informs ATC that a higher minimum speed is required for safety reasons) 200 KIAS max within 4 nm and 2500 ft AAL, (except with ATC approval)

			NON-CONTROLLED
		CLASS E	**CLASS G**
		Within continental Australia outside radar coverage above FL180 where Class A base is FL245 Within radar coverage in specific locations or corridors under Class C or Class A airspace. Generally base 8500 ft AMS Surrounding or overlying some CTR Some low-level terminal airspace when the associated TWR is closed	Airspace which is not Class A-E **Note:** Conditions of operating in Restricted Areas over-ride the existing Airspace Classification
IFR	Radio RQ	YES	YES
IFR	Transponder RQ	YES—including ADS-B OUT	YES—including ADS-B OUT
IFR	SUBJ ATC clearance	YES, (unless conducting IFR pick-up)	NO
IFR	Separation provided	IFR from IFR (except during a VFR departure, or when conducting VFR climb or descent)	NO
IFR	Service provided	ATC service and traffic information about known VFR flights as far as practicable	Traffic information about other IFR and known VFR flights as far as practicable
IFR	Speed limits	250 KIAS max below 10,000 ft AMSL (unless a higher minimum speed is required for safety reasons)	250 KIAS max below 10,000 ft AMSL (unless a higher minimum speed is required for safety reasons)

Source: CASA

The AIP defines an air traffic control service as:

> A service provided for the purpose of:
>
> a. preventing collisions:
>
> (1) between aircraft; and
>
> (2) on the manoeuvring area between aircraft and obstructions; and
>
> b. expediting and maintaining an orderly flow of air traffic.

An air traffic control service is provided in controlled airspace, such as in Class A, C, D and E airspace in Australia. These classes of airspace have a separation standard for aircraft operating in these control areas. In controlled en route[23] airspace with surveillance services, the minimum separation requirements between IFR aircraft are 5 NM lateral separation and 1,000 ft vertical separation.

A flight information service (FIS), such as that provided in Class G airspace, is defined in the AIP as:

> A service provided for the purpose of giving advice and information for the safe and efficient conduct of flights.

A flight information service differs from an air traffic control service in that pilots are not provided with positive separation between aircraft, and there are no separation standards for aircraft. Instead, pilots of IFR flights are provided with traffic information, and are required to comply with the rules of the air to maintain their own separation (see the sections titled *Rules of the air* and *Flight information service*).

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23 The en route phase of a flight is defined as the segment of flight from the termination point of a departure procedure to the origination point of an arrival procedure.

Air traffic control surveillance

Both AEM and JQF were broadcasting ADS-B and SSR and were identified by the controller, therefore the pilots were receiving traffic information through a surveillance service rather than a procedural information service. All aircraft information on the controller's display is filtered to update once every 5 seconds (see the section titled *Recorded data*)

The Manual of Standards (MOS) Part 172 (paragraph 10.2.3) required controllers to verify level information being broadcast by aircraft as being within ±200 ft, and that:

> ATC must verify displayed pressure altitude-derived level information:
>
> a. On initial contact with the aircraft or, if this is not feasible, as soon as possible after initial contact; and
>
> b. By simultaneous comparison with:
>
> i. Altimeter-derived level information received from the same aircraft by radiotelephony.

On first airborne contact with each aircraft, the controller validated the altitude information provided by the pilots in the radio transmissions against the altitude displayed on the controller's console. At this check AEM was indicating 100 ft higher than the pilot reported (6,100 ft rather than the reported 6,000 ft), as it was again when the pilot reported the start of descent for airwork at Mangalore. The altitude displayed on the controller display matched the altitude reported by the pilot of JQF. This was within tolerance for both aircraft.

Flight information service

At the time of the accident, AIP GEN 3.3 paragraph 2.16 outlined the traffic information provided in Class G airspace. This information was available to both pilots and controllers. Key information in this section of the AIP included:

> 2.16.1 In Class G airspace, a traffic information service is provided to IFR flights about other conflicting IFR and observed VFR flights.
>
> 2.16.1.1 An IFR flight reporting taxiing or airborne at a non-controlled aerodrome will be advised of conflicting IFR traffic which is not on that CTAF.
>
> 2.16.1.2 An IFR flight inbound to a non-controlled aerodrome will be advised of conflicting IFR traffic. The ATS obligation to provide the pilot with traffic information ceases when the pilot reports changing to the CTAF.
>
> 2.16.1.3 Traffic information will continue to be provided about an IFR flight following cancellation of its SARWATCH[24], until expiry of the flights ETA. Traffic information may be provided to an IFR pilot who has cancelled SARWATCH where workload and communications permit.
>
> 2.16.2 In accordance with the preceding paragraphs, traffic information will be provided to IFR flights when:
>
> a. requested;
>
> b. notifying intention to change level;
>
> c. reporting either taxiing or airborne or departure, whichever is first; or
>
> d. the ATS officer becomes aware of conflicting traffic.
>
> 2.16.3 Pilots of IFR aircraft should advise ATS of the callsign(s) of relevant IFR traffic, previously intercepted, to avoid receiving the same traffic information from ATS.
>
> 2.16.4 Traffic information will be provided in accordance with the preceding paragraphs whenever there is a possibility of confliction between aircraft in the following situations:

---

[24] SARWATCH: A generic term covering search and rescue alerting based either on full position reporting procedures, schedule reporting times or SARTIME (the time nominated by a pilot for the initiation of search and rescue action if a report has not been received by the nominated unit.

a. aircraft that climb, descent or operate with less than 1,000 ft vertical spacing and less than 15 NM lateral or longitudinal spacing;

b. overtaking or opposite direction aircraft on the same or reciprocal tracks with less than 1,000 ft vertical spacing and less than 10 minutes longitudinal spacing based on pilot estimates;

c. more than one aircraft arriving at, or departing from, the same aerodrome with less than 10 minutes between arrival and/or departure and falling within these guidelines.

2.16.5 When the traffic assessment is based entirely on the use of an ATS surveillance system, traffic information will be provided when, in the opinion of the controller, it is warranted by the proximity of the aircraft to each other.

2.16.7 Traffic information will include relevant factors from the following:

a. the identification of the conflicting aircraft;

b. the aircraft type;

c. the route of the aircraft;

d. the last position report received from the aircraft;

e. intentions of the pilot (if known), and, as required;

f. the aircraft's initial departure track and intended cruising level;

g. inbound track or direction, level and next estimate; and

h. any other data which may enhance the value of the information.

An ATS surveillance service is defined in the AIP as a:

> Term used to indicate an air traffic service provided directly by means of an ATS surveillance system.

An ATS surveillance system is defined in the AIP as:

> A generic term meaning variously, ADS-B, primary surveillance radar, secondary surveillance radar or any comparable ground-based system that enables the identification of aircraft.

AEM and JQF were under a surveillance service, once they were identified by the controller following their first airborne radio calls. Therefore, AIP paragraph 2.16.5 was applicable, with the controller providing traffic information when warranted by controller opinion rather than through the requirements of 2.16.4. There was no requirement for the controller to pass updated traffic information to aircraft that had already received traffic information, even when the information passed no longer accurately reflected the current position the aircraft were in.

An air traffic controller overseeing Class G airspace has the responsibility to provide traffic information to IFR aircraft until they report changing to CTAF. This is a historical procedure that was in place when aircraft commonly only had one radio and remains despite many aircraft being fitted with dual radio systems. However, this procedure remains in the latest edition of the AIP, current 2 December 2021 (AIP GEN 3.3, paragraph 3.3.7.2).

Guidance in the Airservices and Department of Defence Manual of Air Traffic Services (MATS) supports the AIP information, and provides controllers with further advice about how to provide traffic position information to pilots:

9.1.6.5 Position information

Provide position information by:

a. Clock reference;

b. Bearing and distance;

c. Related to a geographical point;

d. Reported position and estimate; or

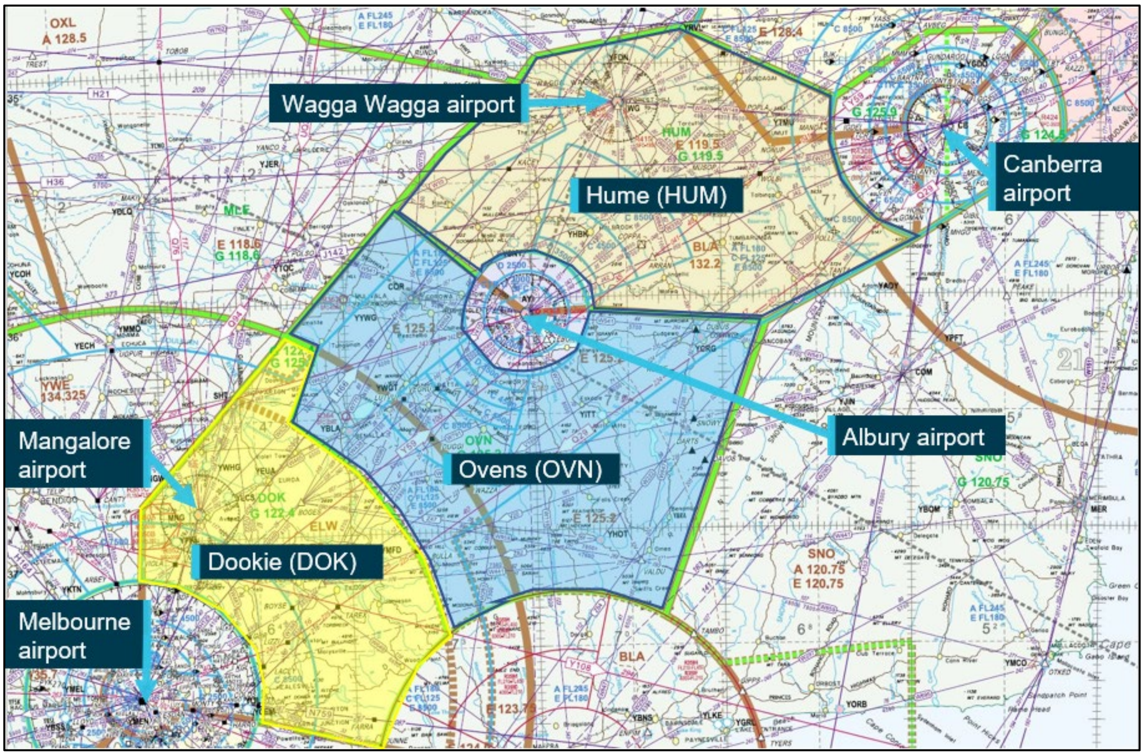
e. Position in the circuit

Airspace

The Melbourne Centre controller was responsible for monitoring a section of airspace known as 'Alpine' that spanned an area from the Melbourne control zone to Canberra (Figure 11). This airspace included Class C and E controlled airspace, as well as Class G non-controlled airspace.

Where workload required, the 'Alpine' airspace can be sub-divided into three sectors – Hume (HUM), Ovens (OVN) and Dookie (DOK). At the time of the accident, the controller was operating the three sectors combined.

Figure 11: Alpine airspace, including Dookie, Ovens and Hume sectors and key aerodromes



Source: Airservices, annotated by the ATSB.

Controller display

Air traffic controllers have multiple screens on their console, displaying information such as a map view of the aircraft in their sector; flight plans of active and future aircraft; weather and NOTAM[25] information. Co-ordination of aircraft passing into their sector may occur either through verbal communication with another controller or through data messages sent between controllers.

The position of AEM and JQF as they operated under a surveillance service were identified through a combination of secondary surveillance radar (SSR) and ADS-B. Airservices advised that, when SSR information was available, this was the primary source of traffic information displayed to the controller. Additionally, data presented to the controller was only updated every 5 seconds (see the section titled *Recorded data*).

ATSB analysis showed that the filtered SSR data and ADS-B data broadcast by each aircraft effectively presented the aircraft in the same relative positions after traffic information was passed to JQF.

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25 NOTAM: A notice distributed by means of telecommunication containing information concerning the establishment, condition or change in any aeronautical facility, service, procedure or hazard, the timely knowledge of which is essential to personnel concerned with flight operations.

The controller had the ability to zoom into sections of the airspace on the display. This gave the controller the ability to further inspect information available about each aircraft, including callsign, altitude and flight plan information. The controller used this function to inspect alerts that were generated (see the section titled *Short term conflict alert*).

Following the accident, Airservices recreated the controller's display for the period that AEM and JQF were operating in Class G airspace. While this did not replicate where the controller had the information labels[26] placed for each aircraft, it did display the same information as the controller would have seen.

The controller operated with the default display setting, with 2 minute velocity vectors projected ahead of each aircraft in their sector. The vectors were based on the current track of the aircraft, and not on any information included in the flight plan. Therefore, following the departure call from the pilot under examination in JQF, when traffic information about AEM was passed to the occupants of JQF (see the section titled *Communication, Melbourne Centre*), the vectors indicated that JQF would pass behind AEM (Figure 13). However, this projected information did not consider the flight planned track and the intent of the pilot in JQF to turn and intercept the Mangalore to LACEY track within 5 NM of Mangalore Airport (see the sections titled *Flight plans* and *Pilot Licencing)*. Unlike the velocity vectors that projected where in space an aircraft would be if they continued on the same track and with the same groundspeed, there was no numerical predictive information provided to the controller relating to the projected altitude of a climbing or descending aircraft in that 2 minute timeframe. If needed, this information had to be determined by the controller through processing a combination of climb or descent arrows, known aircraft performance, flight plan information or speed information.

Short term conflict alert

A short term conflict alert (STCA) is an aural and visual alert received on a controller's console when two aircraft come within a defined proximity of each other. In describing the intent of the STCA, the International Civil Aviation Organization (ICAO, 2016) noted:

> The objective of the STCA function is to assist the controller in preventing collision between aircraft by generating, in a timely manner, an alert of a potential or actual infringement of separation minima.

In the Australian ATC system STCAs occur in both controlled and non-controlled airspace, with alerts inhibited in some areas. Specifically, Airservices advised that STCAs in Class G airspace are inhibited below 4,500 ft in the Brisbane flight information region[27], but occur to the ground in areas of the Melbourne flight information region.

When two aircraft are assessed by the system as likely to pass within prescribed vertical and lateral parameters in a particular time window, the controller will receive a pop-up window on their display with aircraft details. The parameters for an alert on aircraft in Class G airspace are the same as the parameters for aircraft in an en-route controlled environment. Aircraft operating below FL285, under a surveillance service will generate a STCA if they are projected to pass within 4.8 NM and 600 ft in the next 60-90 seconds.

The STCA only alerts for aircraft operating under a surveillance service. Both AEM and JQF were included in this, as they were both operating under a flight plan, broadcasting ADS-B and SSR data, and had both been positively identified by the controller. Some aircraft, such as 2 VFR aircraft in non-controlled airspace operating without a submitted flight plan, will not generate a STCA even if a conflict situation develops.

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[26] The information label provides a controller with information about the aircraft registration, aircraft type, number of passengers on board, current altitude, cleared altitude, groundspeed, and any notes made about the aircraft. Figure 13 shows an example of information labels.

[27] Australia is divided into two flight information regions – Melbourne and Brisbane. Airservices advised that the inhibition within the Brisbane region was due to nuisance alerting.

The procedures documented for the response to a STCA did not differentiate between controlled airspace, where a STCA indicates an infringement of separation minima, and non-controlled airspace where there is no published separation minima.

In terms of prioritisation of alerts, the National ATS procedures manual (NAPM) identified the STCA as one of the highest priority alerts, indicating a system detected safety net critical event, requiring immediate attention.

The response procedure for a controller receiving a STCA was:

> 14.1.3.1 Alert integrity
>
> On receipt of a STCA:
>
> 1. Assess its integrity; and
> 2. Issue a 'Safety Alert' or 'Avoiding Action' advice when appropriate.

The process for 'assessing integrity' of a STCA was undefined. Airservices advised the ATSB that it was an assessment based on controller judgement and experience, and there was no documented checklist or criteria that controllers used to complete this assessment. A STCA may be assessed as not having integrity if the procedure of passing mutual traffic information to two aircraft had been completed, and the aircraft were expected to be self-separating on the CTAF.

It was reported by the controller that it was not unusual to receive a STCA in the airspace being controlled after traffic information was passed. This statement was supported by the Airservices accident investigation report, which noted that other controllers operating the same Alpine sector received a high number of nuisance[28] STCAs. These STCAs activated between aircraft in the circuit or between aircraft on diverging tracks or who had already passed each other. It was reported that IFR aircraft in the vicinity of non-controlled aerodromes often pass within the STCA parameters when self-separating and did not normally need further intervention after traffic information was passed.

After a controller assessed the integrity of a STCA, and determined that escalation was required, the information for controllers in the MATS regarding safety alerts stated:

> 9.1.4.1 Vigilance
>
> Remain vigilant for the development of safety alert or traffic avoidance advice situations
>
> 9.1.4.2 Responsibility
>
> Do not assume that because another controller has responsibility for an aircraft that an unsafe situation has been observed and a safety alert or traffic avoidance advice has been issued.
>
> 9.1.4.3 Issuing a safety alert
>
> Unless the pilot has advised that action is being taken to resolve the situation or that the other aircraft is in sight, issue a safety alert prefixed by the phrase 'SAFETY ALERT' when you become aware that an aircraft is in a situation that places it in unsafe proximity to:
>
> a. Terrain;
> b. Obstruction;
> c. Active restricted or prohibited areas; or
> d. Other aircraft
>
> 9.1.4.3.1 Airspace classes – safety alerts
>
> You may issue safety alerts, including those based on visual observation, in all classes of airspace both within and outside ATS surveillance system coverage.

---

[28] Airservices defined a nuisance alert is 'an alert which is correctly generated according to the defined STCA system parameters (rule set),but is considered operationally inappropriate by the controller.

Advice to pilots in AIP GEN 3.3 current at the time of the accident stated:

5.1 ATC will issue a Safety Alert to aircraft, in all classes of airspace, when they become aware that an aircraft is in a situation that is considered to place it in unsafe proximity to:

a. terrain;

b. obstruction;

c. active restricted or prohibited areas; or

d. other aircraft.

5.1.1 When providing an ATS surveillance service, ATC will issue advice to pilots regarding avoiding action as a priority, when they become aware than an aircraft is in a situation that is considered to place it at risk of collision with another aircraft

5.1.2 ATC will prefix advice to turn or change level with “suggest” unless the alerts are for controlled flights with reference to other controlled flights.

5.1.3 ATC may discontinue issuing Safety Alerts or advice regarding avoiding action when the pilot has advised action is being taken to resolve the situation or has reported the other aircraft in sight.

The AIP guidance for safety alerts stated that pilots would receive a safety alert whenever two aircraft were deemed by a controller to come within an unsafe proximity of each other, whether in controller or non-controlled airspace. When the combination of the MATS and NAPM guidance was followed after receipt of a STCA, a safety alert may not be issued if the controller deemed other risk controls were in place such that the proximity was safe. However, the guidance did not preclude a safety alert being issued when a controller deemed it necessary after a STCA, or at any other time.

There was no definition for what ‘unsafe proximity’ between aircraft was when operating in non-controlled airspace under pilot separation as there was no separation standard in non-controlled airspace. Further, when pilots were in the vicinity of a CTAF and had been provided traffic information, there was an expectation from controllers that the pilots were in radio contact with each other and self-separating.

The information in MATS regarding traffic avoidance advice was:

9.1.4.4 Traffic avoidance advice

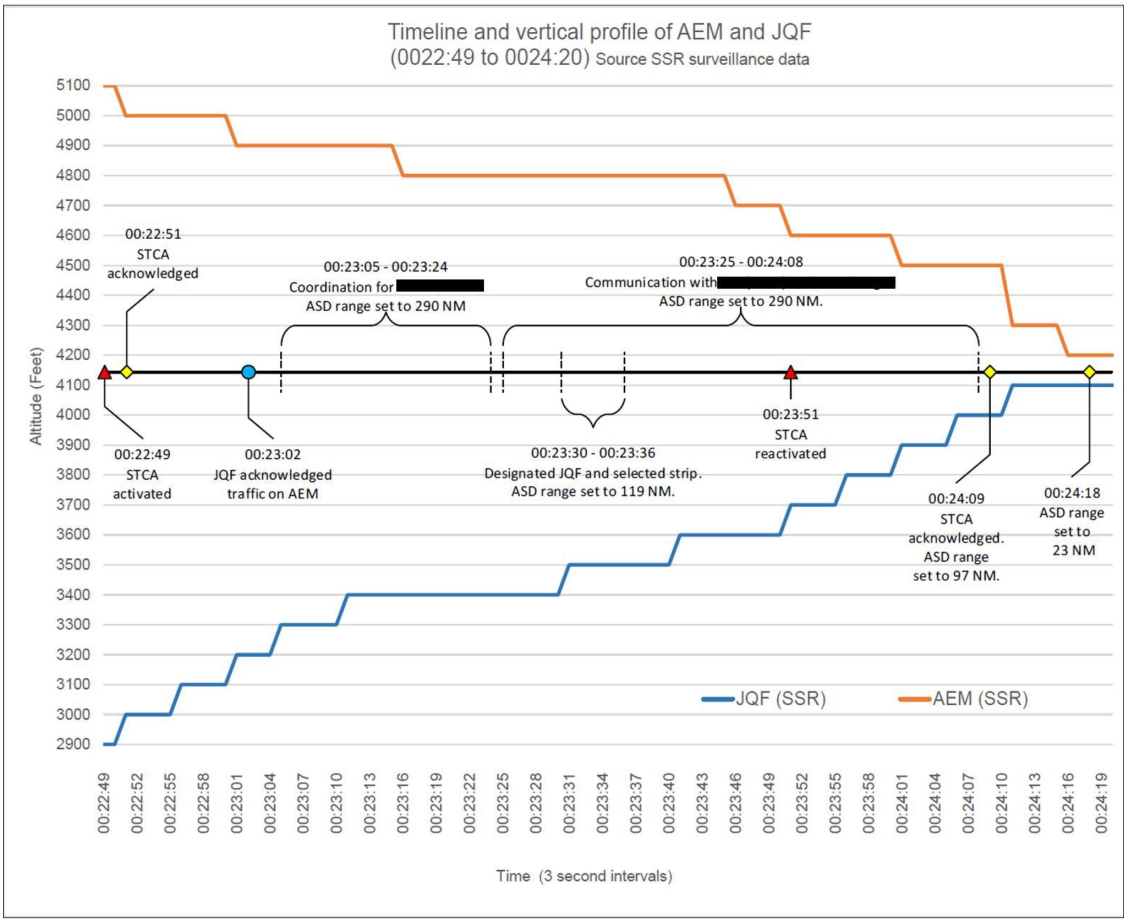
Issue traffic avoidance advice, prefixed by the phrase ‘AVOIDING ACTION’, to an aircraft that:

a. Is receiving an ATS surveillance service; and

b. In your judgement, is in a situation that places it at risk of a collision with another aircraft under surveillance.

In the time between JQF taking off and the collision, there were three STCA alerts generated (Figure 12).

Figure 12: STCA activation and vertical profiles of AEM and JQF



Source: Airservices

Notes:

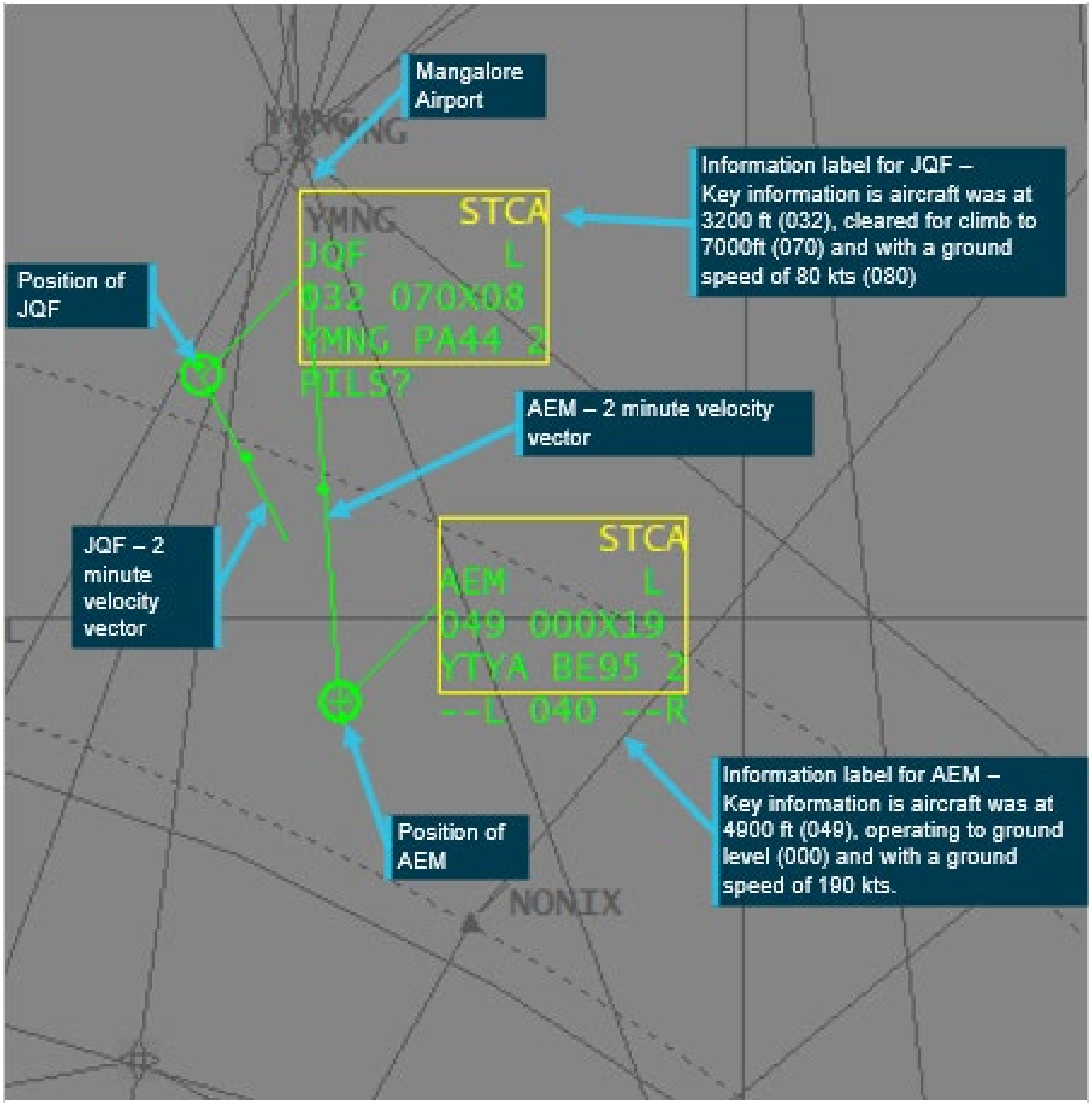
- Callsigns of other aircraft redacted. Controller was actively communicating with either pilots or other controllers at these times.
- ASD is an abbreviation for 'Air Situation Display', meaning the controller display.
- Times on the graph are displayed in UTC (local time – 11 hours at the time of the accident).
- Data is displayed in graph in 3 second intervals, and is not representative of the 5 second intervals that the controller display was updated with.

On the basis of analysis conducted by an ATC subject matter expert and technical detail provided by Airservices, it was assessed that:

- The first STCA, at 1122:42, was a nuisance alert generated by JQF conflicting with VFR traffic in the Mangalore circuit area.
- A second STCA, at 1122:49, occurred as the controller passed traffic information to JQF (Figure 13). At that stage, indications were that the aircraft would pass abeam each other. The STCA was assessed by the controller but not cleared from the screen at this point.
- The controller re-inspected the two aircraft at 1123:30 after JQF had turned towards the planned outbound track. The velocity vectors indicated that lateral displacement would be maintained, with JQF passing behind AEM in about one minute. At that time, the controller's display showed AEM at 4,800 ft while JQF was at 3,400ft.

A final STCA alert occurred at 1123:51. The controller zoomed in to inspect the aircraft flight paths and altitudes again and acknowledged the STCA at 1124:09. The controller identified that JQF was going to pass across the track of AEM, but at that time, 11 seconds prior to the collision, indications on the controller's display showed AEM at 4,500 ft and JQF at 4,000 ft, with 0.9 NM lateral separation between the aircraft.

Figure 13: Recreation of STCA display at 1122:49



Source: Airservices data, annotated by the ATSB

Note: Not to scale or necessarily representative of how the controller had the labels configured.

When each of the STCAs displayed, the controller assessed the integrity of the alert in accordance with the NAPM procedure. The controller reported checking the path of each aircraft using the set velocity vectors, the vertical separation of the aircraft, and confirming that traffic information about each aircraft had been passed to the other aircraft. Having assessed that the aircraft would pass each other and:

- the STCA was designed as an alert for a breakdown in separation standards
- there was no set separation standard in non-controlled airspace
- the pilots were responsible for their own separation

they decided that a safety alert or traffic avoidance advice was not required, and cleared the aural alert.

Radio communication

Common traffic advisory frequency

Table 3 shows the guidance provided by CASA (2019) to pilots on the recommended CTAF broadcasts in the vicinity of a non-controlled aerodrome.

Table 3: Recommended positional broadcasts in the vicinity of a non-controlled aerodrome

Recommended calls in all circumstances		
Item	**Situation**	**Broadcast**
1	The pilot intends to take-off.	Immediately before, or during Taxiing.
2	The pilot is inbound to an aerodrome.	10 NM from the aerodrome, or earlier, commensurate with aeroplane performance and pilot workload, with an estimated time of arrival (ETA) for the aerodrome.
3	The pilot intends to fly through the vicinity of, but not land at, a non-controlled aerodrome.	10NM from the aerodrome, or earlier, commensurate with aeroplane performance and pilot workload, with an estimated time of arrival.

Source: CASA (2019)[29]

In addition to this guidance, the En-Route Supplement Australia (ERSA)[30] identified a local procedure for pilots to make a report about intentions when conducting practice instrument approaches at Mangalore (see the section titled *Practice instrument approaches*). The ERSA also noted the following minimum number of radio calls for aircraft operating at Mangalore:

> Taxiing, entering (a runway), departing: Inbound, Joining, Base and Final with position, altitude and intentions.
>
> *Note: Pilots must respond to radio requests from other traffic for their intentions, position or altitude.*

Based on evidence provided by other students trained by the instructor, due to the higher performance of the Travel Air, the instructor encouraged students to make their inbound CTAF call around 15 NM from the airport. The operator of JQF advised that they had a similar procedure to make CTAF broadcasts around 15 NM from Mangalore Airport.

Radio transmissions on the Mangalore Airport common traffic advisory frequency (CTAF) were not recorded, nor were they required to be. Several witnesses stated the CTAF was often congested, but due to the weather at the time of the accident, there was limited flight training and so the CTAF was not as busy.

The ATSB interviewed the pilots operating in the Mangalore area at the time of the accident regarding calls made from the pilots of AEM and JQF. None recalled the pilots of AEM and JQF talking to each other to arrange separation. Various pilots recalled a pilot in JQF making a rolling call, and a departure from the circuit call, and one pilot remembered details of an inbound call made by a pilot of AEM, including mention of an altitude of 3,900 ft.

[29] CASA Civil Aviation Advisory Publication (CAAP) 166-01 v4.2 Operations in the vicinity of non-controlled aerodromes. February 2019.

[30] The ERSA is part of the Airservices Australia Aeronautical Information Service suite of documents.

The CTAF frequency at Mangalore was not equipped with an aerodrome frequency response unit (AFRU)[31]. There was no evidence to suggest either aircraft had selected the incorrect radio frequency or that an AFRU would have changed the sequence of events. The radios installed in AEM were too damaged to be analysed, but notes found in the aircraft, and details provided by another pilot about an inbound call from AEM, indicated it was likely that AEM broadcast on the correct CTAF frequency.

The two radios from JQF were recovered and analysed by the ATSB. One was set to the Melbourne Centre frequency and the other to the Mangalore CTAF. The audio panel configuration was found in a position consistent with the pilots of JQF either broadcasting or intending to broadcast on the CTAF.

Melbourne Centre

The required radio reports for IFR pilots operating in Class G airspace are listed in the AIP (Table 4). Transmissions between each aircraft and the controller were made on the ATS Melbourne Centre 122.4 MHz frequency and were recorded.

Table 4: Required reports for IFR pilots operating in Class G airspace

SUMMARY OF REPORTS - IFR AIRCRAFT IN CLASS G AIRSPACE (*Note: Requirements of para 10.1.13 apply*)		
Situation	**FREQ to Use**	**Remarks**
Taxiing	ATS	Report
Departure	ATS	Departure Report
Reaching cruising level	ATS	Report
Position report at prescribed and nominated points	ATS	Report
Previously notified position estimate > 2 minutes in error	ATC	Report
Before changing level	ATS	Report
Changing frequency	ATS	Report
For clearance into controlled airspace	ATC	Report
Before leaving controlled airspace on descent	ATS	Report
Changing to CTAF and not monitoring ATC FREQ on second COM system	ATS	Report
Joining circuit	ATS	Report *
After landing	ATS	Report *
* Report required only if cancelling SARWATCH at this time.		

Source: AIP

[31] The aerodrome frequency response unit system is designed to assist pilots with the correct selection and volume of a CTAF frequency. When an AFRU is coupled to a CTAF the name of the CTAF is announced after a radio broadcast if the frequency has been dormant for more than 5 minutes. If a broadcast has been made in the previous 5 minutes, a 300 millisecond tone is generated.

Table 5 outlines the communications that occurred between each of the aircraft and the controller providing traffic information (see the section titled *The occurrence*). A review of the radio recordings confirmed that the pilot of JQF made taxi and departure calls to Melbourne Centre. The student in AEM also made the appropriate calls when changing to the Melbourne Centre frequency and before changing level, when they started the descent from 6,000 ft into Mangalore.

Table 5: Key traffic information on Melbourne Centre frequency

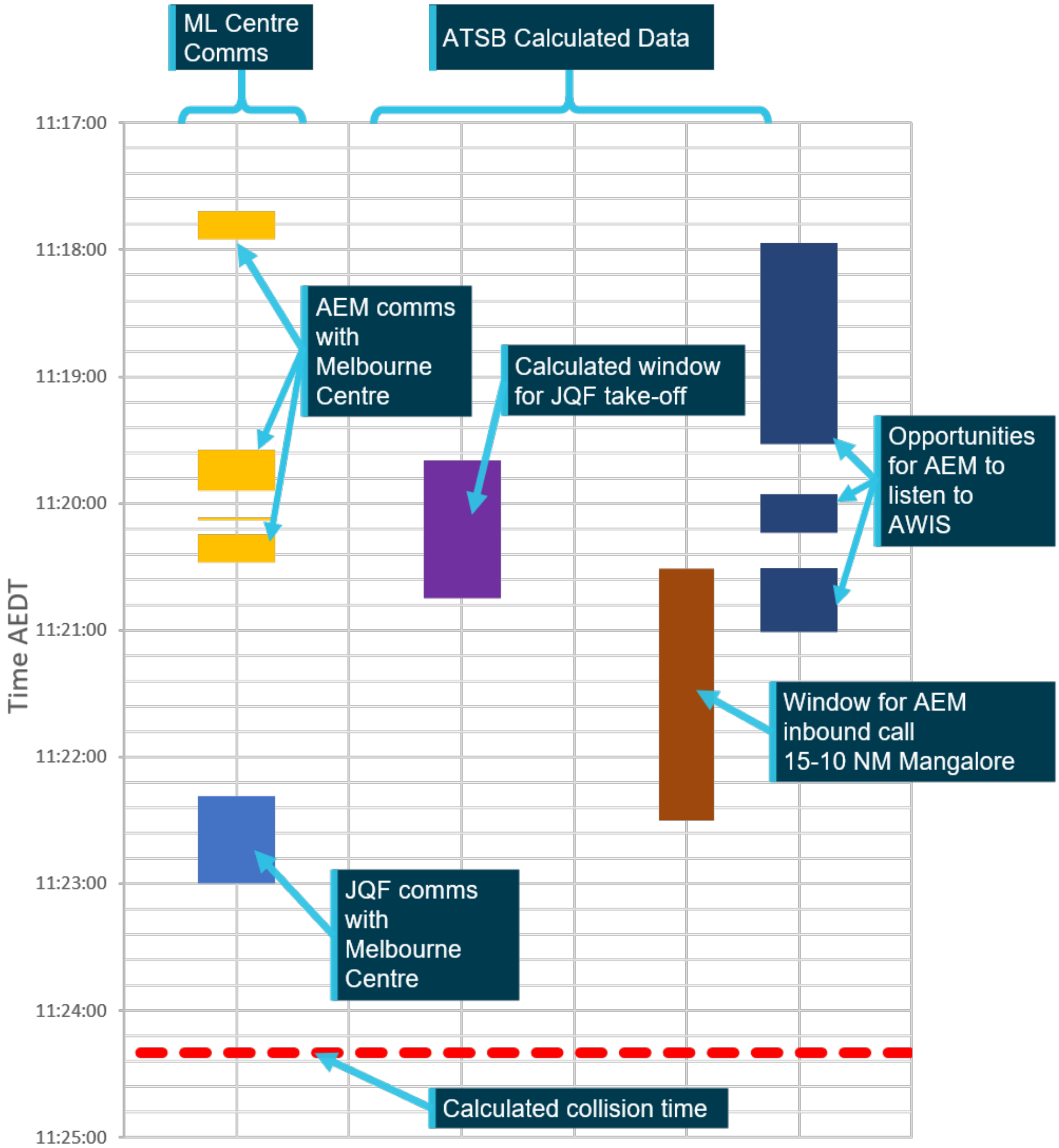
Time start (* indicates approximate time)	Time end (* indicates approximate time)	Aircraft	Comment
1111:21	1111:32	JQF	Taxi call
1117:42	1117:55	AEM	Initial contact with controller on entry to airspace. Area QNH provided and advice of no reported IFR traffic.
1119:35	1119:54	AEM	Controller contacted with information about commencing descent from 6,000 ft and establishing a SAR time for airwork in the Mangalore area. Advice of no reported IFR traffic provided by the controller.
1120:07	11:20:08	AEM	Controller called the pilots of AEM to pass traffic. No response received.
1120:15	1120:28	AEM	Controller again called the pilots of AEM. Pilot responded and traffic information about JQF shortly to depart Mangalore was passed and acknowledged.
11:22:19	1123:00	JQF	Departure report to controller. Information was provided that the aircraft was passing 2,700 ft on climb to 7,000 ft and tracking to LACEY. Controller advised the pilots that AEM was inbound to Mangalore in JQF's 12 o'clock position, for airwork, passing 5,000 ft on descent to not above 4,000 ft. During this conversation a STCA for proximity between AEM and JQF activated and was acknowledged by the controller.
1123:51	1124:09		STCA for AEM and JQF. Controller zoomed in on screen and acknowledged the STCA at 1124:09.
1124:20			Approximate time of collision

Source: Airservices, annotated by the ATSB

A review conducted by Airservices following the accident concluded that both aircraft were provided with, and acknowledged receipt of, mutual traffic that contained all relevant information. They also assessed that pilot communications with the controller were generally consistent with the AIP phraseology and the required content was included in the transmissions. A subject matter expert was independently asked by the ATSB to review the recordings, and confirmed that the controller provided traffic in accordance with the procedures in the AIP and MATS.

Figure 14 details analysis conducted by the ATSB of ADS-B data and Melbourne Centre recordings provided by Airservices.

Figure 14: Approximate timeline of transmissions and key actions from 1117 to the collision



Source: ATSB, based on data provided by Airservices

Note: Radio transmissions on the Melbourne Centre frequency were recorded so correspond to exact times (see Table 5). The ATSB calculated data is based on ADS-B data. Due to a lack of available information, the following assumptions were made:

- The start of the JQF take off, at 1120:00 corresponds to the first recorded ADS-B point, which occurred when the aircraft was approximately one third down the runway and around 50ft above the runway. It is likely that the pilot's rolling call, and the start of the take-off roll occurred some seconds before this time. The time from application of power to attaining a height of 50ft has been estimated to be 20-25 seconds.
- The pilots of AEM had a number of opportunities to listen to the Automated Weather Information Service (AWIS)[32] – before and after the descent call to the Melbourne Centre controller at 1119:35. As the aircraft was fitted with two radios, the pilots would likely have selected the AWIS frequency instead of the CTAF for the period of time required. This means they were unable to monitor the CTAF for this time period. A previous student of the instructor described setting up the AWIS frequency in the cruise so that it could be listened to as soon as it came into range, and before top of descent.

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32 Automated Weather Information Service (AWIS): actual weather conditions, provided via telephone or radio broadcast, from Bureau of Meteorology automatic weather stations.

When the pilot under examination in JQF made a taxi report at 1111, AEM was not yet in the controller's airspace. Therefore, at that point AEM was not assessed as conflicting traffic and so no information was provided to the pilots of JQF. Additionally, the expected arrival time of AEM at Mangalore was outside the 10 minute window to be considered arriving 'traffic' for JQF in accordance with the guidance provided in AIP GEN 3.3 paragraph 2.16.4c for non-surveillance traffic. The controller indicated awareness of this in interview with the ATSB.

AEM was not given traffic information about JQF when they first called the Melbourne Centre controller at 1117, or initially at 1119 when calling to notify their descent. While JQF had made the taxi call to Melbourne Centre by that time, JQF had not appeared on the controller's screen as a prompt at that point.

However, the controller did identify JQF as potential traffic for AEM by 1120:07, and called the pilot of AEM. The pilot did not initially respond to this call, however, they did respond to a second call from the controller a short time later at 1120:15. It could not be determined why the pilot did not respond to the initial call, but consideration was given to whether the pilots were listening to the automated weather information services (AWIS) (see the section titled *Meteorological information*) or making an inbound call on the CTAF as at this point they were about 18 NM from Mangalore. The information given to the pilots of AEM was that JQF was shortly to depart Mangalore southbound via LACEY on climb to 7,000 ft.

Analysis of high resolution ADS-B information identified that JQF's take-off coincided with the pilots of AEM's call to Melbourne Centre to inform of their descent into Mangalore for airwork. This timing suggests that the pilots of JQF were unlikely to have been actively monitoring transmissions on the Melbourne Centre frequency at this time, including advice of AEM's descent, due to their focus on the take-off.

AEM reached 15 NM from Mangalore at around 1120:30, just as they finished receiving traffic information from the Melbourne Centre controller. This is the position that previous students of the instructor identified that the instructor encouraged students to make their inbound call. The aircraft reached 10 NM around 1122:30 (Figure 14), which is the latest point the student should have made an inbound call in accordance with expected CTAF procedures. It is therefore likely that an inbound CTAF broadcast was made during this 2 minute time period. Significantly, that time interval coincided with the time that JQF was in the initial climb, and making a departure call to Melbourne Centre. Therefore, it is possible that the pilots of JQF did not hear this inbound call, nor the pilots of AEM hear the CTAF circuit departure call or the Melbourne Centre departure call from JQF.

AIP GEN 3.4 paragraph 6.16.8 contained information about the standard phraseology expected from pilots making reports after take-off in particular operating environments. The standard phraseology for a departure report made from a non-controlled aerodrome in a non-surveillance environment was:

> DEPARTED (location)(time in minutes) TRACKING [TO INTERCEPT] (track) CLIMBING TO (intended level) ESTIMATING (first reporting point) AT (time)

The standard departure report phraseology from non-controlled aerodromes under surveillance when notifying departure and identification was expected with the departure report was:

> (location reference departure aerodrome) PASSING (current level) CLIMBING TO (intended level) ESTIMATING (first reporting point) AT (time)

AIP ENR 1.1 paragraph 10.6.4 also includes the information

> If the pilot transmits the departure report before intercepting the departure track the report must include advice that the aircraft is manoeuvring to intercept departure track.

Radio communication between the Melbourne Centre controller and the pilot under examination in JQF after take-off was as follows:

1122:19	JQF to ML Centre	Melbourne Centre, juliet quebec foxtrot departure

1122:22	ML Centre to JQF	juliet quebec foxtrot's identified, verify level with departure
1122;27	JQF to ML Centre	juliet quebec foxtrot departure at Mangalore two three passing two thousand seven hundred on climb to seven thousand tracking to LACEY, Mangalore.
1122:37	ML Centre to JQF	juliet quebec foxtrot area QNH one zero one zero
(Note this call was interrupted internally by another Melbourne controller)		
1122:41	JQF to ML Centre	One zero one zero, juliet quebec foxtrot
1122:44	ML Centre to JQF	And juliet quebec foxtrot, traffic six [nautical] miles in your 12 o'clock is alpha echo mike a king air, they're inbound to Mangalore for airwork, passing five thousand on descent to not above four thousand.
1123:00	JQF to ML Centre	Copy (unintelligible) traffic juliet quebec foxtrot.

While the controller positively identified JQF, the statement made was by the pilots of JQF that they were tracking to LACEY, without the specific information that they were tracking to intercept the IFR airway from Mangalore to LACEY (Figure 10). Additionally, it did not include detail of the position of JQF with reference to Mangalore, which at the time of the departure report was about 2.2 NM south-south-west of the airport. While it could not be determined whether the pilots of AEM heard this departure report, the information had the potential to provide them with an incorrect mental model of the aircraft's relative position. The Airservices investigation report identified that at this time the two aircraft had 8.6 NM lateral separation, and 2,600 ft vertical separation.

There was also a discrepancy with the traffic information, in referencing AEM as a King Air rather than a Travel Air. However, that was unlikely to have had a significant impact on the understanding of the presence of traffic, or its performance, as the groundspeed of AEM was similar to the approach speed of the type of King Air that frequented Mangalore Airport.

Based on the information presented by the velocity vectors, when giving this traffic information the controller judged that JQF would pass behind AEM.

While it would not be expected, as traffic self-separation broadcasts would generally be made on the CTAF, a review of the recording confirmed that neither aircraft attempted to contact the other using the Melbourne Centre frequency.

A review of the air traffic control recordings and transcripts indicated that between 1123:12 and 1124:08, the controller was actively engaged with other aircraft, or co-ordinating aircraft with another controller. It was during this time that the final STCA for the two aircraft occurred.

Automatic dependent surveillance broadcast

Overview

ICAO (2018) defined automatic dependent surveillance broadcast (ADS-B) as:

> A means by which aircraft, aerodrome vehicles and other objects can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.

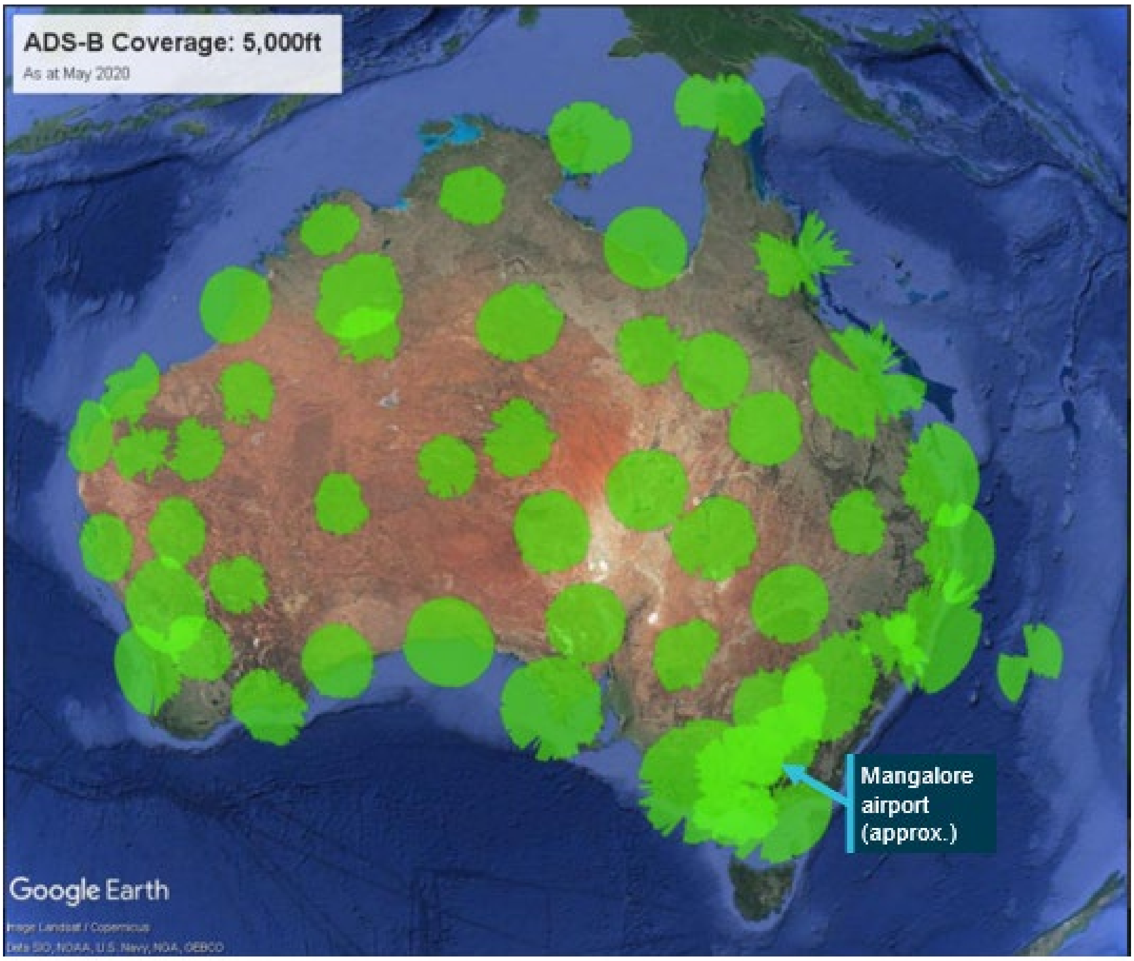
ADS-B uses the GNSS for positioning. ADS-B data can be both broadcast (ADS-B OUT) and received (ADS-B IN).

Under Civil Aviation Orders 20.18, both AEM and JQF were required to be fitted with ADS-B OUT equipment to operate under the IFR. Both aircraft were fitted with transponders that complied with this requirement.

To provide an ADS-B based surveillance service, Airservices has a range of ground-based ADS-B receivers. The resulting ADS-B coverage at an altitude of 5,000 ft across Australia is shown in

Figure 15. Mangalore Airport was within the coverage area at this altitude. ADS-B coverage improves as altitude increases, and at 30,000 ft almost all flights within Australia can be conducted under an ADS-B surveillance service.

Figure 15: ADS-B coverage at 5,000 ft across Australia



Source: Google Earth and Airservices, annotated by the ATSB.

Cockpit traffic display

Neither aircraft was fitted with a system to receive ADS-B information directly from other aircraft, nor were they required to be. As such, all the positional guidance the pilots had about other traffic was received from the controller and via any received radio broadcasts.

It is possible to receive ADS-B information from other aircraft directly into an aircraft. Aircraft that are fitted with such a receiver (ADS-B IN) can be configured with a cockpit display of traffic information (CDTI) to identify where other aircraft are relative to their position.

CDTI may give an image of the traffic over a moving map or directional guidance about the location of other aircraft. Some of these systems are also able to provide audible and visual alerts to pilots about identified traffic risks.

The CASA CNS/ATM guide (2017) identified some limitations with cockpit displays:

> CDTIs will help you spot other ADS-B traffic more easily by showing you where to look. However:
>
> - Depending on the unit's filtering capability, your CDTI might not show all ADS-B traffic
> - CDTIs will not display non-ADS-B traffic
> - Don't try to second-guess ATC instructions with CDTI information

- Do not attempt to take evasive action, or to separate your aircraft from other traffic, using a CDTI. It is there to enhance situational awareness, not to replace separation procedures.

Cockpit display of traffic information does not replace see-and-avoid. You still have to look out the window for other traffic.

Electronic flight bag

The student pilot in AEM was using ‘AvPlan’ electronic flight bag (EFB)[33] software installed on an iPad. In addition to the EFB, this pilot was also carrying a paper flight plan and set of relevant approach charts.

AvPlan has an option to display traffic information overlayed on the map display.

Traffic information can be obtained either by:

- having an external ADS-B receiver attached
- using the ‘AvPlan live’ feature.

Use of the AvPlan live traffic information system required the live tracking feature to be turned on, a data connection and a connection to a GPS position. The iPad in AEM was fitted with a SIM card capable of providing the required data connection to AvPlan live, but was not fitted with an external ADS-B receiver. The AvPlan user manual identified that traffic displayed using the AvPlan live function was from:

> …other connected airborne AvPlan EFB users, a network of ADS-B ground receivers, and FLARM[34] ground receivers.

Data displayed using AvPlan live was updated every 5 seconds, rather than every second when an ADS-B receiver was attached. The software had no capability to identify aircraft using other EFB software, or non-ADS-B equipped aircraft. The AvPlan user manual noted:

> Note that this traffic is a great start for situational awareness, however it does **not** include **all** traffic. Always be on the lookout/maintaining a listening watch for traffic.

Due to the damage to the tablet sustained in the impact, it was not possible to recover data from the iPad to determine whether the traffic information overlay display was selected at the time of the collision.

The ADS-B ground receiver network used by AvPlan for traffic information was not the same as the network used by Airservices for receiving ADS-B data, and there was limited coverage for the AvPlan network in the Mangalore area. Information provided by AvPlan after the accident identified that aircraft in the approximate location of the collision, 5 NM south of Mangalore airport, were not visible as traffic on AvPlan below approximately 4,900 ft. Therefore, as the pilots in JQF were not carrying an AvPlan-connected iPad and it was unlikely that the AvPlan ADS-B ground network received broadcasts from JQF it is probable that JQF would not have appeared as traffic on the iPad used in AEM, even if the traffic information overlay had been selected.

The use of an external ADS-B receiver significantly increases the frequency of updated traffic information and receives ADS-B broadcasts directly from ADS-B OUT equipped aircraft within range of the receiver. Information from the AvPlan user manual stated:

> When AvPlan EFB is connected to an ADS-B receiver, traffic as far as the receiver can observe will be displayed. Traffic sources from the receiver will be coloured green to allow quick identification of a traffic target’s source. No height or distance limitations are placed on traffic delivered by an attached device. Traffic received via this method is updated once every second”.

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33 Electronic flight bags can electronically store and retrieve documents required for flight operations, such as maps, charts, the Flight Crew Operations Manual, Minimum Equipment Lists and other control documents. See CASA CAAP 233-1

34 FLARM is a collision avoidance system that shows other similarly equipped aircraft in the vicinity.

At the time of the accident, neither AvPlan nor OzRunways, another Australian EFB provider, provided audible alerts about proximal traffic, although at the time of writing AvPlan offered this feature.

Collision avoidance systems

ADS-B also has the ability to feed into an aircraft collision avoidance system (ACAS). Neither aircraft were required to have ACAS fitted.

In describing ACAS, the ICAO (2021) stated:

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

By providing pilots with visual information about where other aircraft are operating in their proximity, pilots are able to make more timely decisions based on displayed information and take avoiding action, thereby reducing the risk of collision.

At present in Australia, there are no regulatory requirements for aircraft of the size and operational category involved in this accident to have any form of ACAS fitted to the aircraft.

In 1991 the Bureau of Air Safety Investigation (the predecessor to ATSB) issued the Civil Aviation Authority (the predecessor to CASA) with a recommendation that:

> In light of the serious limitations of the see-and-avoid concept, the CAA should closely monitor the implementation of TCAS[35] in the US and should consider the system for Australia.

In 1998, CASA accepted this recommendation and stated the system would be introduced when cost effective.

Under the current regulations in Australia, an approved ACAS must be fitted any turbine-engine aeroplanes operating under Part 121 (Australian Air Transport Operations – Larger Aeroplanes) that:

> Paragraph 11.21
>
> a. Either:
>
> i. has a maximum take-off weight of more than 15,000kg; or
>
> ii. has a maximum certificated passenger seating capacity of more than 30; or
>
> b. Is first registered, in Australia or elsewhere, on or after 1 January 2014, and:
>
> i. has a maximum take-off weight of more than 5,700 kg but not more than 15,000kg; or
>
> ii. has a maximum certificated passenger seating capacity of more than 19 but not more than 30.

Aircraft operating under Part 135 (Australian Air Transport Operations – Smaller Aeroplanes) must be fitted with an approved ACAS if they are turbine-engined, have a maximum take-off weight of more than 5,700kg and was first issued with a certificate of airworthiness on, or after, 1 January 2014. There are no regulations requiring fitment of an ACAS to aircraft equivalent to AEM and JQF.

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35 Traffic alert and collision avoidance system (TCAS): a type of airborne collision avoidance system (ACAS).

Meteorological information

Forecast weather

The Bureau of Meteorology (BoM) produced a terminal area forecast (TAF)[36] for Mangalore Airport and the surrounding area, and a graphical area forecast (GAF)[37] for Victoria. The forecast conditions at the time of the accident included scattered cloud at 2,500 ft AMSL[38] and between 3,500 ft and 6,000 ft AMSL. Visibility was forecast to be greater than 10 km, and the wind from the south-west (230°) at 15 knots at ground level, with gusts up to 25 knots. The grid-point wind and temperature forecast listed the wind at 5,000 ft as from 210° at 32 kt.

Actual weather

The aerodrome weather report (METAR/SPECI) issued at 1130, 6 minutes after the collision, identified the presence of three cloud layers - broken layers at 3,000 ft and 3,700 ft AMSL[38] and an overcast layer at 4,500 ft.

At the time of the accident, the automatic weather service (AWS) at Mangalore Airport recorded two cloud layers: one scattered at about 3,500 ft AMSL[38] and a second broken layer at 4,200 ft (about the collision altitude).

Three photographic sources were also reviewed to assess the likely cloud conditions at the time of the accident. Figure 16 identifies the locations where these images were recorded.

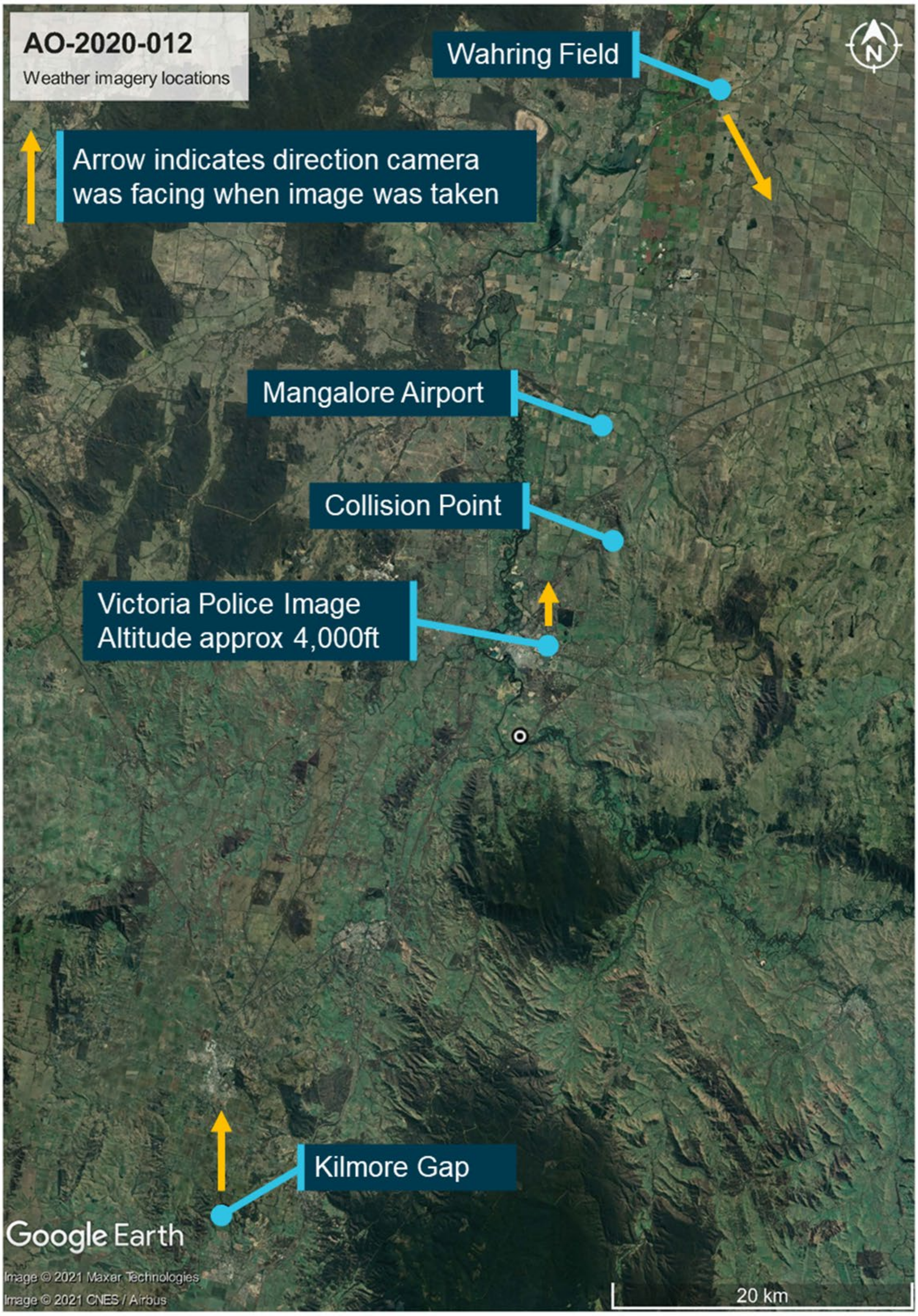
---

36 Terminal Area Forecast – a statement of meteorological conditions expected for a specific period of time in the airspace within a radius of 5 NM (9 km) of an aerodrome's reference point.

37 Graphical Area Forecast – provides information on weather, cloud, visibility, icing, turbulence and freezing level in a graphical layout with supporting text. These are procedure for 10 areas across Australia, broadly State-based.

38 Cloud information recorded by the AWS and published in the TAF and METAR/SPECI references cloud heights in feet above ground level (AGL) rather than above mean sea level (AMSL). The ground level elevation at Mangalore Airport is 467 ft AMSL, therefore approximately 500 ft has been added to the AGL cloud layers in the BoM weather information to provide context on where the cloud layers sat for the two aircraft.

Figure 16: Location of photographic sources used in the cloud assessment



Source: Google Earth, annotated by the ATSB

Figure 17 shows an image recorded by a BoM weather camera at Kilmore Gap (elevation 1,731 ft), looking north towards Mangalore Airport at the time of the collision.

Figure 17: Weather camera image from Kilmore Gap facing towards Mangalore Airport

Source: BoM

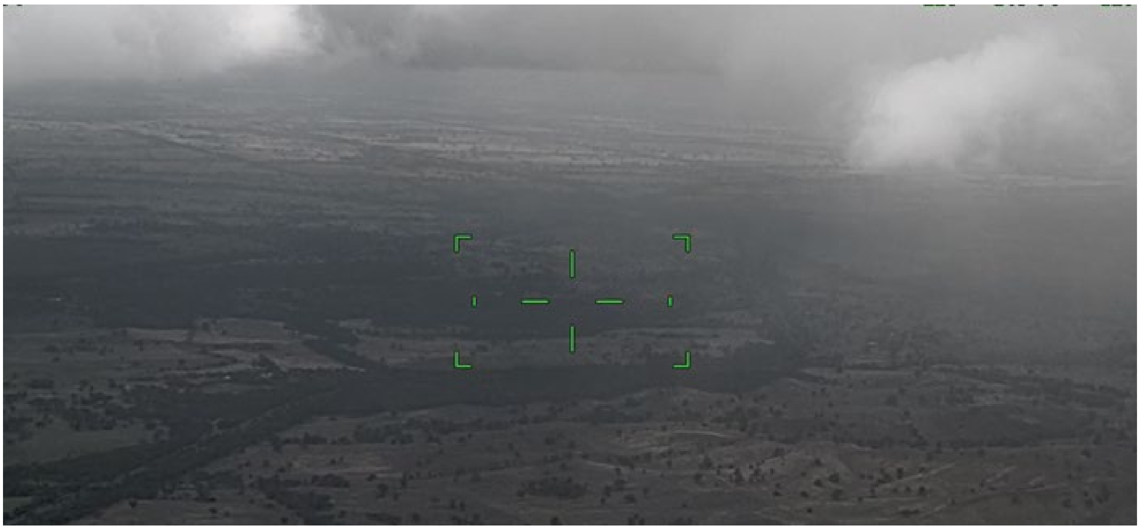
A similar image was recorded at Wahring Field (elevation 410 ft) looking in a south-east direction at 1120 (Figure 18)

Figure 18: Weather camera at Wahring Field

Source: BoM

Video imagery recorded by the Victoria Police Air Wing (Figure 19) near the accident site at 1240, 1 hour and 16 minutes after the accident showed a broken layer of cloud at approximately 4,050 ft AMSL with some lower patches of cloud also present. This is just below the approximate height of the collision (4,100 ft)

Figure 19: View of cloud from the Victoria Police Air Wing helicopter



Source: Victoria Police

The observed cloud conditions were marginally poorer than forecast, but still suitable for the flights. The observations show scattered, broken and overcast cloud layers with bases below, at, and above the collision altitude.

Information from the automatic weather service was available to pilots on an aerodrome weather information service (AWIS) radio frequency. It is likely that the pilots of AEM checked this information before making their inbound CTAF call.

Recognising that both the aircraft were operating under the IFR, AIP ENR 1.2 defined the criteria required for pilots to maintain visual meteorological conditions (VMC) (Table 6).

Table 6: Criteria to maintain VMC in Class G airspace

2.5 **Non-Controlled Airspace - Class G**

Item	Type of Aircraft	Height at which Applicable	Applicable Distance for Flight Visibility	Applicable Distances for Vertical and Horizontal Distances from Cloud Visibility	Conditions
1.	Aeroplanes, heli-copters and balloons	At or above 10,000FT AMSL	8KM	1,000FT vertical 1,500M horizontal	
2.	Aeroplanes, helicopters and balloons	Below 10,000FT AMSL (Subject to Items *3, 4, 5, 6 and 7, below*)	5,000M	1,000FT vertical 1,500M horizontal	
3.	Aeroplanes, heli-copters and balloons	At or below - whichever is the higher - of: (a) 3,000FT AMSL; (b) 1,000FT AGL (Subject to *Items 4, 5, 6 and 7 below*)	5,000M	Clear of cloud and in sight of ground or water	Radio must be carried and used on the appropriate frequency

At the time of the collision a scattered cloud layer was observed at Mangalore Airport at 3,500 ft and a broken layer at 4,200 ft, encompassing the collision altitude. However, just 6 minutes after the accident the lower cloud layer was observed to be broken. The later Police video showed that the broken cloud base was about 4,000 ft with some lower patches. The observations recorded over the time between the accident and the Police helicopter arriving indicated the weather remained similar, with only a slight increase in cloud base of about 100 ft.

Therefore, at the time of the collision, the aircraft were probably near a layer of scattered to broken cloud, and just below a further broken to overcast cloud layer. Consequently, as AEM descended it is probable that the aircraft was surrounded by cloud until passing through about 4,500 ft. While the aircraft may not have been in cloud at the time of the collision, the extensive surrounding cloud would have reduced conditions to significantly below VMC, reducing the opportunity for visual acquisition by any of the pilots.

Aerodrome information

Overview

Mangalore Airport has an elevation of 467 ft. The airport has four paved runways – 05/23 and 18/36[39]. At the time of the accident, runway 23 was in use. The airport is used for a variety of general aviation purposes, including a high volume of ab-initio pilot training. There are no scheduled regular public transport operations to the airport.

There was no specific data collected by the airport about the number of aircraft using Mangalore Airport however, the CASA Office of Airspace Regulation (OAR) provided the ATSB with the traffic information used for monitoring risk at Mangalore airport, which was provided to them by Airservices. This traffic information is summarised in Table 7 (see the section titled *Airspace oversight)*.

Table 7: Mangalore Airport movement data

Mangalore Movement Data for the 12 months ending					
Month/Year	Total Movements	Air Transport Movements	Passengers	VFR Movements	IFR Movements
December 2015	10,800	1,555	6,000	9,392	1,408
December 2016	9,900	1,321	5,600	8,630	1,270
December 2017	7,218	836	4,057	6,298	920
December 2018	8,900	1,063	4,400	7,906	994
December 2019	8,372	1,001	4,183	7,392	980
December 2020	9,100	1,131	4,800	7,984	1,116

Source: CASA

Local flight procedures

The ERSA current at the time of the accident included a number of notes that identified several local flight procedures for the airport. Three of these were applicable to the operations of AEM and JQF. The procedure requiring additional radio calls above the standard requirements at non-controlled aerodromes has been previously discussed (see the section titled *Common traffic advisory frequency*)

Practice instrument approaches

Note 2 stated:

> Except as required during instrument rating tests, pilots making practice instrument approaches should add 1,000 ft to the altitude prescribed in the approach to reduce interference with Mangalore AD circuit traffic. Such flights must broadcast their intentions, including altitude limits of OPS. Similarly, pilots making instrument approaches in IMC on encountering VMC are required to remain as high as practicable and join the circuit in the standard manner.

39 Runway number: the number represents the magnetic heading of the runway.

Records from CASA indicated that this local procedure first appeared in the Mangalore ERSA in July 1997. The airport manager provided information to the ATSB that this procedure was requested by a flying school to assist with the separation of instrument approach traffic from circuit traffic. Airservices and CASA were unable to provide any further background about this procedure.

This procedure is not unique to Mangalore Airport, the ERSA also described similar local procedures at Ballarat, Busselton, and Latrobe Valley airports. In a review of Ballarat Airspace published in August 2017, OAR received stakeholder feedback that IFR training aircraft were incorrectly approaching Ballarat without the required additional 1,000 ft of height stated in the ERSA. In response, OAR made a recommendation that:

> CASA should provide specific information to IFR pilots that frequent Ballarat about the additional 1,000 ft procedure.

Interviews conducted by the ATSB established that the two operators involved in this accident interpreted and applied this ERSA local procedure differently. Specifically:

- Previous students of the instructor in AEM applied 1,000 ft to the minimum decision altitude only, flying the approach as published and discontinuing early.
- The operator of JQF stated that they required pilots to add 1,000 ft to all heights identified on the chart. However, they stated that while they were aware that the two largest flying schools using Mangalore Airport applied it this way, there were other operators that applied the procedure the same way as the operator of AEM.

When the ATSB requested clarification about the intention of the wording of the procedure, CASA advised that:

> This procedure is to be applied by adding the 1,000 ft to all waypoints and the MDA.

Landing lights

Note 3 stated:

> It is recommended that all ACFT shall illuminated LDG and taxi lights WI a 10 NM radius of the airport and when established in the circuit.

Due to the extent of damage, investigators were unable to determine whether AEM had landing lights switched on. Examination of JQF identified the landing lights were switched on at the time of impact however, it is also noted that landing lights have a relatively narrow beam and therefore are only visible from the frontal aspect of an aircraft.

Recorded data

Neither aircraft was equipped with a flight data recorder or a cockpit voice recorder, nor were they required to be, due to their size and type of operation. In January 2021, the ATSB issued a safety recommendation to CASA (Safety issue number AO-2017-118-SI-03) recommending the consideration of mandating the fitting of onboard recording devices for passenger-carrying aircraft with a maximum take-off weight less than 5,700 kg. A second recommendation (Safety issue number AO-2017-118-SI-04) was also made to the International Civil Aviation Organization (ICAO):

> The Australian Transport Safety Bureau recognises that the International Civil Aviation Organization has developed technical standards for lightweight recorders and airborne image recorders. However, despite the known benefits for the identification of safety issues, the fitment of such devices for passenger-carrying aircraft with a maximum take-off weight less than 5,700 kg is not mandated. The Australian Transport Safety Bureau recommends that the International Civil Aviation Organization takes safety action to consider the safety enhancement of these devices to passenger-carrying operations.

Airservices provided the ATSB with two sources of data relating to the accident flight:

- Filtered ADS-B and radar data showing the aircraft as they appeared on the controller's display. This data was filtered to approximately 5 second intervals.
- Raw ADS-B data captured from the ADS-B receivers. This information captured the ADS-B out data from each aircraft at intervals of less than 1 second. This data was not available to the controller at the time, but has been used for the aircraft performance and visibility study (see the section titled *Aircraft performance and cockpit visibility study*)

Flight data received from the EFB used by the student in AEM was also provided by AvPlan. This ADS-B data matched the data provided by Airservices.

No data was recoverable from any of the instruments on board either aircraft.

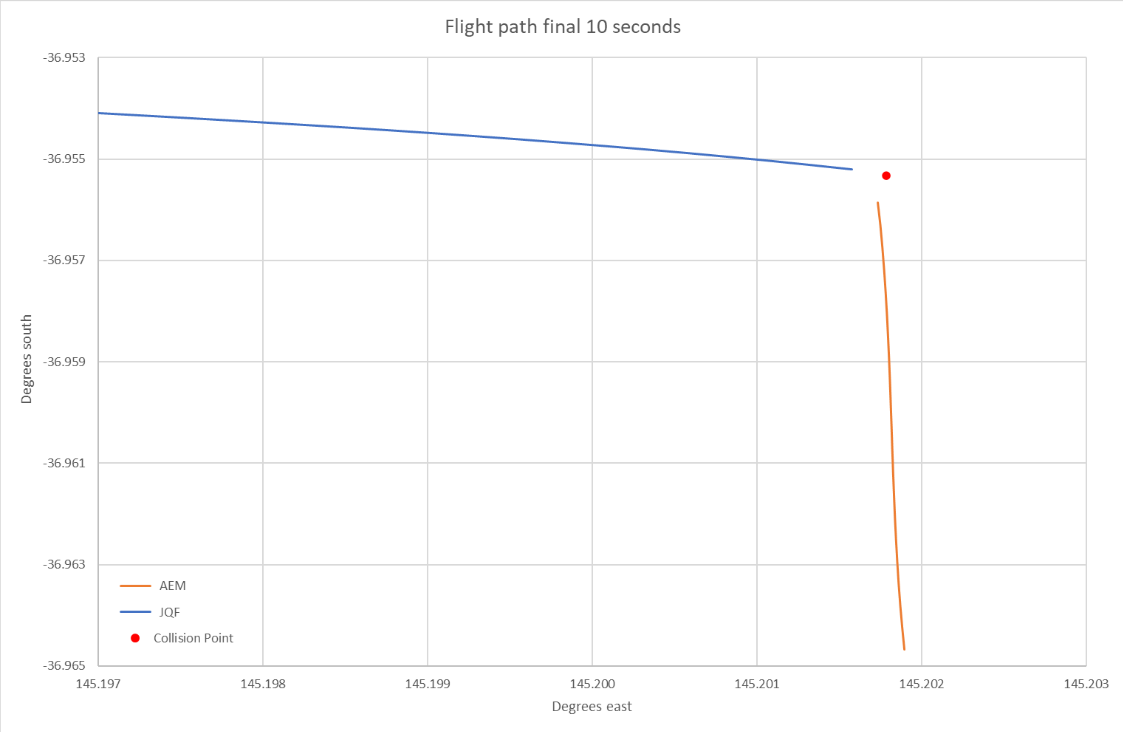
Flight path data

The raw ADS-B data was analysed to determine how the two aircraft came together. The data indicated that approximately 0.55 seconds before the collision AEM was on a true heading of 352° and JQF on a true heading of 132°, giving a relative heading angle of 140° (Figure 20). At this time JQF and AEM were estimated to be at the same level, 4,125ft, with JQF maintaining altitude and AEM descending on approach to Mangalore (Figure 21, Figure 22). The groundspeeds of JQF and AEM, considering all available wind information and limitations in the ADS-B data, were around 94 kt and 192 kt respectively with a closing speed just prior to the collision of approximately 245 kt.

The data for AEM showed very little variation in track and the data for JQF showed a slow turn towards the flight planned track to LACEY. Based on the lack of rapid or pronounced change in the aircrafts' flight paths it is unlikely that an evasive manoeuvre was initiated by the pilots in either aircraft. Figure 22 shows the total separation, including both lateral and vertical components, of AEM and JQF after the time of JQF's take-off from Mangalore. This illustrates that the two aircraft remained on a collision course for most of the flight.

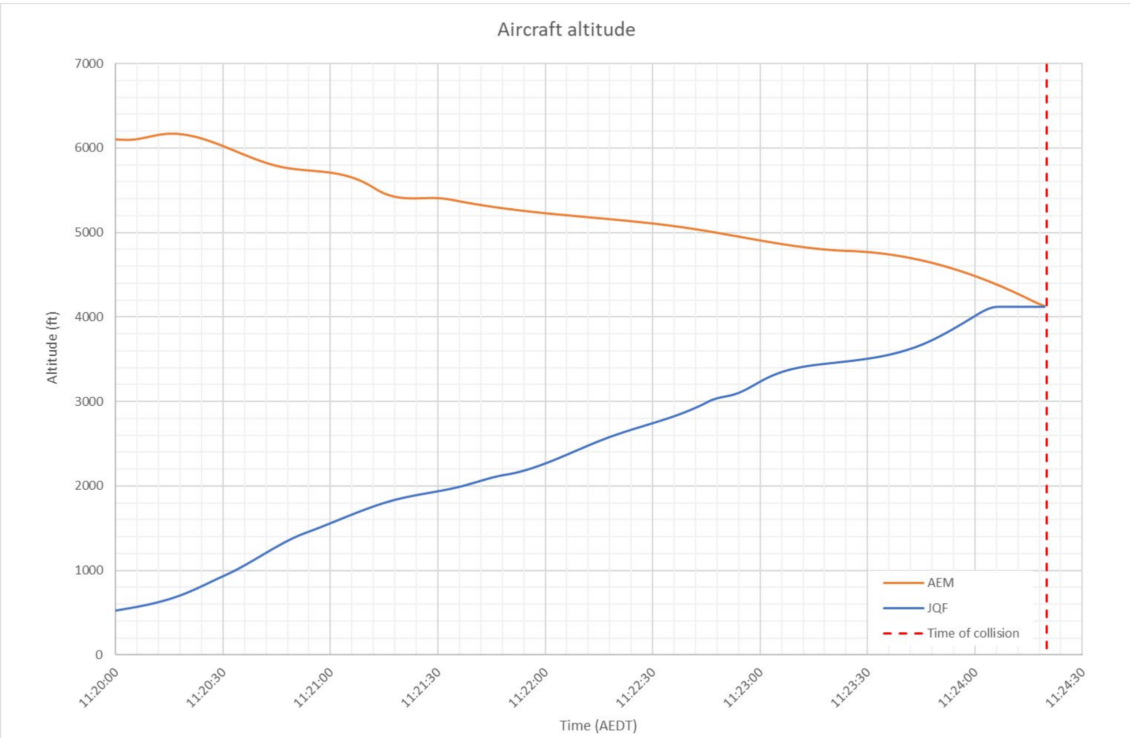
It should be noted that this data was not available to the controller at the time of collision. However, this information would have been available to the pilots of AEM and JQF had both aircraft been fitted with additional ADS-B IN technology.

Figure 20: Aircraft position for AEM and JQF



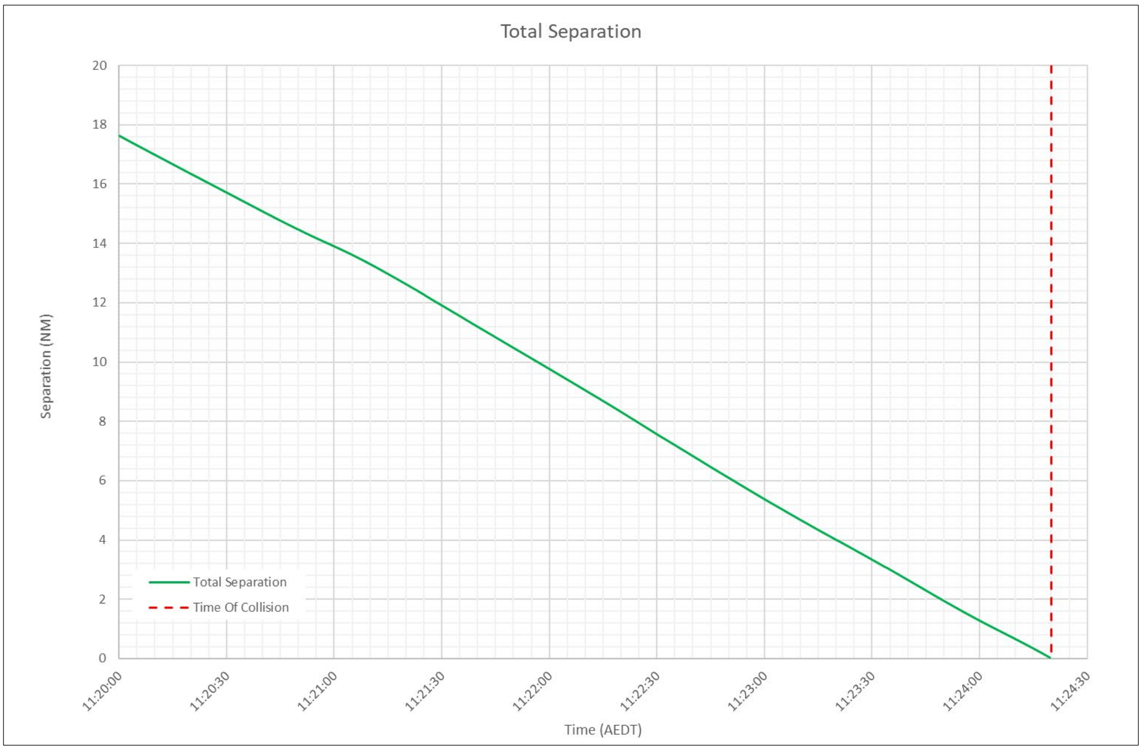
Source: ATSB, based on data provided by Airservices.
Note: Due to wind, the angle of approach (track angle) will appear smaller than the angle of collision (heading angle).

Figure 21: Vertical profile and timeline for AEM and JQF



Source: ATSB, based on data provided by Airservices.

Figure 22: Total separation between AEM and JQF in nautical miles



Source: ATSB, based on data provided by Airservices.

Wreckage and impact information

Overview

Following the mid-air collision, JQF continued for about 0.5 km before impacting an open field, while AEM continued in a northerly direction and impacted a lightly wooded area about 1.4 km from the collision point (Figure 23).

Airborne debris liberated in the collision formed a further wreckage field about 1.6 km to the north-north-east of the collision point and about 200 m to the west of the Hume Highway. The debris field contained parts of both aircraft, including the front section of JQF's right wing, and the instrument panel coaming from AEM.

Inspection of both aircraft identified paint transfer from the other aircraft. A blue paint transfer was noted on the instrument coaming of AEM, indicating that the right wing of JQF had passed through the cabin area of AEM. After contact between the two aircraft, JQF likely lost a section of the right wing outboard of the engine nacelle, which was the piece found separate from the two aircraft.

Figure 23: Locations of collision, AEM, JQF and debris field

Source: Google Earth and Airservices, annotated by the ATSB,

VH-AEM site

The Travel Air was found in a significantly disrupted state, and it was not possible to conduct an extensive examination of the engines and aircraft control systems.

From observations of the wreckage and damage to nearby trees and ground scars, it was established that the aircraft collided with the ground in a wings-level but steep, inverted attitude. The aircraft passed through the tree canopy and collided with flat ground, the right wing impacted the base of a large tree, a post, and a fence. The wreckage trail was on a heading of 355º, just right of the aircraft's track prior to the collision, with the wreckage spread along a 30-metre path, from the initial impact point to the resting position of the aircraft.

The examination of the airframe and engine systems did not identify any pre-existing defects likely to have contributed to the accident. Flight data showed the aircraft was descending in a stable attitude, until the mid-air collision. Site inspection indicated that the landing gear and flaps were retracted at impact with the ground.

VH-JQF site

Witnesses reported seeing JQF in a spinning descent prior to the collision with terrain, which is supported by the wreckage examination. The aircraft impacted terrain in a relatively flat attitude.

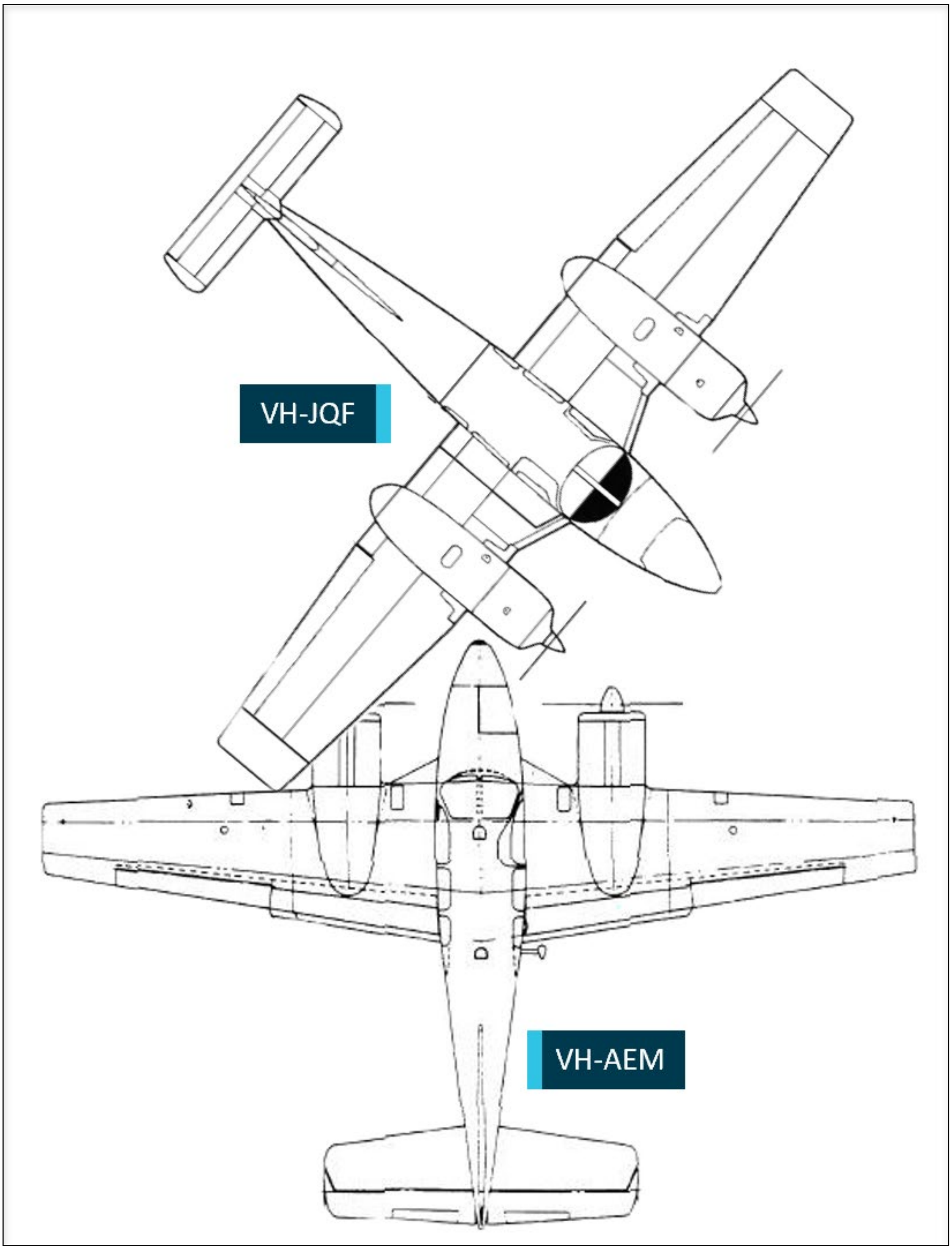
The examination of the airframe and engine systems did not identify any pre-existing defects likely to have contributed to the accident. Flight data showed the aircraft was level immediately prior to the mid-air collision.

All components of JQF were accounted for at the accident site with the exception of some of the right-wing sections, which were located in the debris field to the north of JQF's location, and the right aileron mass balance weight, which was located inside the wreckage of AEM.

The collision

Analysis of the wreckage from each aircraft indicated that the two aircraft came together at an obtuse relative angle with JQF crossing over the top of the AEM (Figure 24).

Figure 24: Estimated collision aspect based on ADS-B data and wreckage assessment



Source: ATSB.

Airspace oversight

Under the *Airspace Act 2007*, CASA, through their OAR was responsible for regulation of all Australian airspace. This included the classification of airspace.

Section 13 of the *Airspace Act 2007* specified that:

> (1) CASA has the function of conducting regular reviews of the existing classifications of volumes of Australian-administered airspace in order to determine whether those classifications are appropriate.
>
> (2) CASA has the function of conducting regular reviews of the existing services and facilities provided by the providers of air navigation services in relation to particular volumes of Australian-administered airspace in order to determine whether those services and facilities are appropriate.
>
> (3) CASA has the function of conducting regular reviews of Australian-administered airspace generally in order to identify risk factors and to determine whether there is safe and efficient use of that airspace and equitable access to that airspace for all users of that airspace.

The Australian Airspace Policy Statement 2018 outlined the process for reviewing the classification of a volume of airspace at an aerodrome. The thresholds set for conducting an airspace review were based on a set number of either total annual:

- aircraft movements;
- public transport operation movements; or
- public transport operation passengers.

If an airport met or exceeded any of the thresholds for a classification (Table 8), in line with the policy CASA should complete an airspace review of the particular volume of airspace. The purpose of a review was to determine whether the airspace classification was appropriate and whether additional air traffic services was required, considering public, industry and agency comments, forecast future traffic levels, and any other significant risk mitigators.

Table 8: Airspace review criteria thresholds

	Class B	Class C	Class D
Service provided	ATC	ATC	ATC
Total annual aircraft movements	750,000	400,000	80,000
Total annual PTO aircraft movements	250,000	30,000	15,000
Total annual PTO passengers	25 million	1 million	350,000

Source: Australian Government (2018)

There were no requirements for the review of airspace where aircraft movements or passenger numbers did not meet the thresholds identified, however there was a provision in the Australian Airspace Policy Statement 2018, which stated that:

> These criteria do not preclude CASA examining the requirement for airspace changes at other aerodrome locations should CASA consider such examinations is required, for example, on risk of safety grounds.

The available information on recorded aircraft movements and passenger numbers at Mangalore Airport (see the section titled *Aerodrome information*) did not reach the thresholds for the conduct of an airspace review.

Outside the formal review system, the OAR conducted risk assessments on numerous aerodromes and their surrounding airspace. Records provided by CASA indicated that, prior to this accident, these assessments for Mangalore were last conducted in May 2018 and July 2019. Comments associated with these reviews indicated an awareness that the data quality about the known movements was poor, and that there were fluctuations associated with a low number of aircraft movements, and that there has been an increase in Seminole and King Air operations which CASA attributed to training flights.

At the time of the accident, the OAR had not conducted a formal review of the airspace around Mangalore. A 2011 study of the Melbourne airspace noted that Mangalore had a high level of aviation activity, but was outside the scope of the study. CASA launched an aeronautical study of the Mangalore airspace in September 2021. The results of this review had not been released at the time of publication of this report.

The Australian Airspace Policy Statement was updated in November 2021. This update removed the prescriptive thresholds for a review, and instead moved towards risk-based assessments.

Mid-air collisions

See and avoid

In non-controlled airspace, pilots rely on the use of the rules of the air and see-and-avoid to maintain separation from other aircraft sharing the airspace. The limitations of see-and-avoid principle are well published.

The 1991 ATSB report 'Limitations of the See-and-Avoid Principle' is cited extensively in pilot guidance by CASA and foreign regulators and investigators. The paper identified a number of factors that influence the ability for a pilot to see-and-avoid other aircraft. It includes the statement that:

> See-and-avoid can be considered to involve a number of steps. First, and most obviously, the pilot must look outside the aircraft.
>
> Second, the pilot must search the available visual field and detect objects of interest, most likely in peripheral vision.
>
> Next, the object must be looked at directly to be identified as an aircraft. If the aircraft is identified as a collision threat, the pilot must decide what evasive action to take. Finally, the pilot must make the necessary control movements and allow the aircraft to respond.
>
> Not only does the whole process take valuable time, but human factors at various stages in the process can reduce the chance that a threat 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'.

It is likely that the cloud present on the day affected the ability of the pilots to see the approaching aircraft. However, even without this cloud, the ATSB paper identified additional limitations of see-and-avoid:

- Workload – The pilots in JQF were in the climb phase of a test flight and establishing the aircraft on the outbound track. The crew of AEM were conducting the first in-aircraft VOR approach with this student.
- Visual search – A human's field of vision begins to narrow after 35, and significantly after age 55. Additionally, in daylight, a pilot must look almost directly at an object to see it. Therefore it is possible for a pilot to look past an object in their screen if they do not see it directly.

- Cockpit visibility – Items such as engines, window pillars, sunshades, and dirt may impact on the pilot's ability to see an aircraft.
- Time to conduct a traffic scan – Pilots require a long time to effectively conduct a traffic scan, during which time the picture out the window changes due to the motion of the aircraft.
- Limitations of vision – Factors such as the eye's physiological blind spot and the threshold of an individual's vision and the acuity of their vision. Some individuals may perceive another aircraft much further away than others.
- Alerted traffic search – It is estimated that pilots who are told where an aircraft is are around eight times more likely to see the aircraft than pilots who are not alerted to the direction of an aircraft.
- Characteristics of the aircraft – Aircraft are more easily spotted if they have a high contrast with their background
- Relative movement between aircraft – It is difficult to see another aircraft when there is little relative motion between one aircraft and the other, such as when they are moving towards the same location in space. Furthermore, when aircraft have a high closing speed, the small visual angle presented by an aircraft may not grow rapidly until collision is imminent.

In addition to the issues presented with pilots seeing other aircraft, there is evidence that pilots need around 12.5 seconds after they see an aircraft to perceive what it is and respond with an evasive manoeuvre to avoid the collision. The research shows that older or less-experienced pilots need even longer.

Excluding the likely influence cloud had on the opportunity for the pilots of each aircraft to sight the other aircraft; at 12.5 seconds prior to the collision, the angular size that each aircraft would have appeared was only around 0.4°; increasing to around 1° 5-6 seconds pilot to the collision.

Studies have assessed the size an object needs to be for it to be sighted, with estimations varying from 0.2° degrees (NTSB, 1988) to 0.4-0.6° (Morris, 2005). However, these observations may be made under certain conditions, and not reflective of the particular conditions experienced by these pilots.

Collision prevention

The United Kingdom (UK) Airprox[40] board commissioned a research paper (Helios 2014a, 2014b) to review the risk of mid-air collision in Class G airspace. While the particular operation and regulation of Class G airspace in the UK is slightly different from that in Australia, it remains non-controlled airspace, with an available traffic information service.

The research identified seven barriers to mitigate the risk of mid-air collisions (Figure 25). Four of these were preventative, to avoid the occurrence of both conflicting traffic and incidents:

- strategic conflict management,
- pre-tactical events,
- pilot tactical control, and
- ATC tactical intervention,

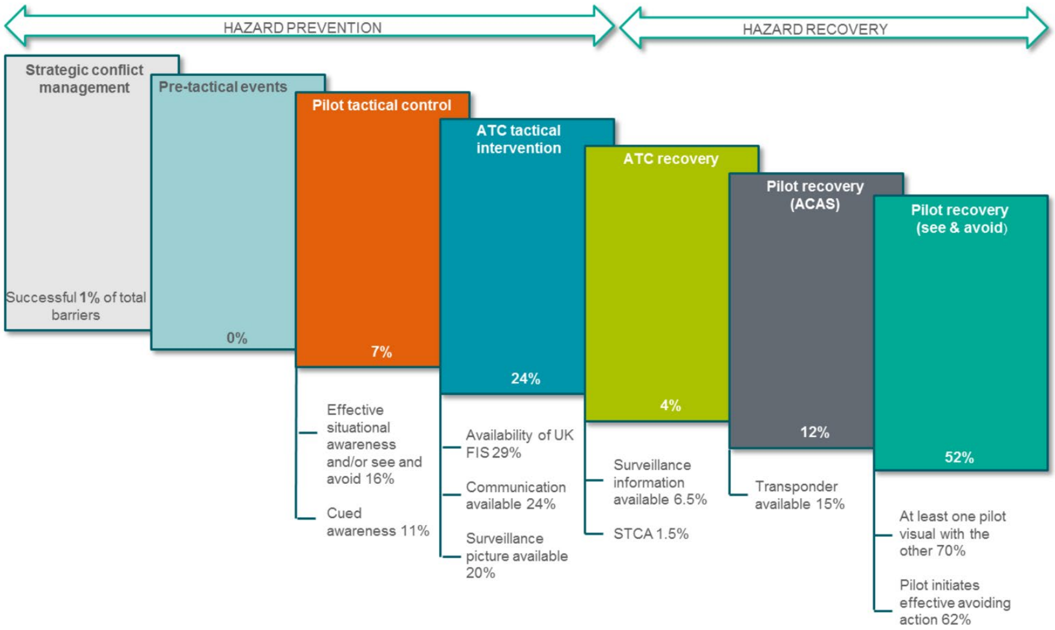
The other three barriers were attempts to stop an incident becoming an accident:

- ATC recovery,
- pilot recovery (ACAS) and
- pilot recovery (see and avoid).

40 Airprox: An occurrence in which 2 or more aircraft come into such close proximity that a threat to the safety of the aircraft exists or may exist, in airspace where the aircraft are not subject to an air traffic separation standard or where separation is a pilot responsibility (Australian definition)

Analysis of all the received UK airprox reports identified that pilot see-and-avoid was the most effective at preventing mid-air collision, but was also the last available defence. The study also found that an alert provided by ATC following a STCA effectively prevented 1.5 per cent of events escalating to collisions.

Figure 25: Barriers of defence in preventing a mid-air collision



Source: Helios, 2014b

Aircraft performance and cockpit visibility study

As previously discussed, the evidence indicates that the collision occurred either in, or very close to, the bottom of a cloud layer (see the section titled *Meteorological information*), with minimal opportunity for the occupants of the two aircraft to see-and-avoid each other.

However, in order to more fully understand the situation presented to the pilots, the ATSB conducted an aircraft performance and cockpit visibility study for this investigation, based on similar work carried out by the United States National Transportation Safety Board[41] and refined for a number of investigations over recent years, most recently for the 2019 mid-air collision near Ketchikan, Alaska (NTSB, 2021).

The study estimated the time windows during which the respective aircraft would have been visible to the pilots in the other aircraft if the accident had occurred in visual conditions. It also assesses the value of the installation and availability of traffic display and alerting systems based on the ADS-B data that both aircraft were transmitting.

This study was conducted as ATSB Safety Study report AS-2022-001. Results of this study indicated that the pilots would have faced significant difficulties in using the see-and-avoid principle to avoid the collision and that ADS-B-based alerting would likely have prevented the accident.

Related occurrences

This is the first recorded mid-air collision between two civil IFR aircraft operating in Australia.

41 The National Transportation Safety Board (NTSB) is the independent transport safety investigation body for the United States of America.

A review of the ATSB's national aviation occurrence database identified that a total of 29 civil mid-air collisions (including this occurrence) were reported in the 20 years between 2001 and 2020. Of these 29 collisions, 21 were classified as accidents, with 12 resulting in fatal outcomes. The remaining 8 collisions did not result in a sufficient level of damage or injury to meet the definition of an accident in the *Transport Safety Investigation Act, 2003* and were instead categorised as incidents or serious incidents.

Of the 28 mid-air collisions, other than this accident:

- One incident was a collision between an aircraft and a parachutist as they exited the aircraft;
- Eight collisions occurred between two gliders (6 accidents with 2 being fatal; 2 serious incidents);
- One serious incident was a collision between a paraglider and a hang glider;
- One fatal accident was a collision between two ultra-light aircraft that reportedly also hit a powerline;
- Three collisions involved two aircraft operating together in either aerial mustering or fire control activities (one fatal accident between two helicopters, one serious incident between two helicopters, and one fatal accident involving a helicopter and an aircraft);
- Three collisions occurred between aircraft conducting formation flying (1 accident, 1 serious incident, 1 incident);
- Four accidents occurred between aircraft on late final approach to land, 2 of which were fatal;
- Five collisions occurred between aircraft operating elsewhere in the circuit – 2 of these were fatal accidents, 2 were accidents with no injuries and one was a serious incident;
- One fatal accident occurred between an aircraft departing from an airport and one conducting aerial agriculture work in the vicinity of the aerodrome; and
- One fatal accident occurred between two aircraft converging at the approach point to an airport.

All of the aircraft involved in these 28 mid-air collisions were operating under visual flight rules. Twenty six of the 28 mid-air collisions occurred in non-controlled airspace. Nineteen of these occurred within 10 NM of an airport, aerodrome or authorised landing area.

Apart from this accident, in the same 20-year period there have been 25 other airspace-related occurrences reported to the ATSB in the vicinity of Mangalore Airport.

Eleven of the 25 occurrences were categorised as a near collision[42]; four of which involved one aircraft operating under the IFR, and one that involved both aircraft operating under the IFR. All eleven occurrences were categorised as serious incidents.

Two of these serious incidents were investigated by the ATSB and are summarised below:

- AO-2011-119: Airprox - VH-CIX/VH-KHG, Piper PA-28-151/PA-44-180, Mangalore Airport, Victoria on 27 September 2011

  While conducting circuits, the Piper PA-28 came within close proximity of a Piper PA-44 rejoining the circuit following an instrument approach, resulting in the crew of the PA-28 taking evasive action. Both aircraft were operated by the same company.

  As a result of the incident the operator introduced a procedure whereby, when the wind conditions favoured a take-off towards the north or north-east, aircraft joining the circuit

[42] Near collision is an ATSB categorisation when 'an aircraft comes into such close proximity with another aircraft either airborne or on the runway strip, or a vehicle or person on the runway strip, where immediate evasive action was required or should have been taken'.

from a practice instrument approach were to descend to an overfly height of 2,000 ft AMSL and join the circuit from the non-active side of the circuit.

- AO-2014-006: Near collision involving a Cessna 404, VH-VEC and a Piper PA-28, VH-UNW near Mangalore Airport, Victoria on 10 January 2014

  The pilot of a Cessna 404 aircraft registered VH-VEC (VEC) was conducting an aerial survey flight north-east of Mangalore Airport, Victoria. The flight was being conducted under the instrument flight rules (IFR) and flown at about 1,500 ft above ground level. The survey pattern required the aircraft to fly across the extended centreline of runway 36. The pilot made all required CTAF broadcasts while operating in the area.

  At the same time as VEC was conducting the survey, several aircraft were departing Mangalore for a series of different navigational exercises. The pilot of VEC continually attempted to call the pilots in the departing aircraft, to establish their position and intentions. However, as per their training, the pilot's did not respond until their respective aircraft were at least 500 feet above the ground. Also, due to misunderstanding the pilot of VEC's intentions, they did not respond to his radio calls, unless the request was directed at their particular aircraft. When the solo student pilot of VH-UNW (UNW) departed runway 36, they focussed on flying the aircraft rather than communicating, until reaching 500 feet above ground level. The pilot of UNW then lowered the aircraft nose to check for traffic and saw VEC in close proximity. In response, they turned UNW to the right at the same time that the pilot of VEC initiated a climbing turn to the right.

Both of these near collisions involved a conflict between a VFR and IFR aircraft in the CTAF area. In the near collision in 2014, separation between the two aircraft was reduced to 100 m horizontally and 200 ft vertically. In the earlier occurrence the separation was 30-45 m horizontally, and at the same level.

One of the other near collisions in the CTAF area at Mangalore involved two aircraft operating under the IFR. One of those aircraft was VH-JQF, the same aircraft involved in this collision. A summary is below:

ATSB Occurrence 201200571: The Piper PA-44 was tracking outbound in the VOR holding pattern when another PA-44 crossed its path in close proximity, tracking inbound to the NDB at the same level.

At the time of writing, the ATSB is investigating another separation occurrence between two aircraft near Mangalore Airport on 6 June 2021 (AO-2021-023). In this incident, an Augusta Westland 139 helicopter was flying southbound toward Mangalore at an altitude of 3,100 ft. At the same time, a PA-44 was conducting an instrument approach to Mangalore.

Due to cloud conditions, the PA-44 commenced a missed approach from below 2,000 ft in a northerly direction toward Mangalore. Shortly after the PA-44 began climbing, and prior to the pilot broadcasting that the missed approach had been commenced, the pilot of the AW139 received a traffic collision and avoidance (TCAS) alert and manoeuvred the aircraft to increase separation. Both flights continued without further incident. A final report for this investigation is due to be published in the second quarter of 2022.

Safety analysis

Introduction

The two aircraft, VH-AEM and VH-JQF, collided in mid-air south of Mangalore Airport. This was the first recorded mid-air collision of two civil, instrument flight rules (IFR) flights in Australia, although not the first event where two IFR aircraft have come into close proximity with each other.

Site and wreckage examination did not identify any aircraft defects or anomalies that might have contributed to the accident. Additionally, no evidence was found to suggest any medical or fatigue-related issues that would have likely affected pilot performance on the day of the flight.

Both aircraft involved in the accident were fitted with Automatic Dependent Surveillance Broadcast (ADS-B) OUT equipment which broadcast positional information. However, neither aircraft had the capability to directly receive this information. Flight path data did not support an evasive manoeuvre being initiated by either aircraft, suggesting that the pilots of both aircraft did not see each other in sufficient time prior to the collision to initiate avoiding action.

This analysis will examine how the two aircraft flight paths conflicted without the risk of a collision being identified and the accident prevented. Further, it will review the controls that could be used to prevent similar accidents from occurring in the future.

Operational environment

In non-controlled airspace, pilots hold responsibility for maintaining separation from other aircraft. The rules of the air require pilots to maintain a lookout for other aircraft when conditions permit, to not operate in a way that creates a hazard for other aircraft, and to monitor and broadcast on the appropriate frequency whenever it is reasonably necessary, to avoid the risk of collision.

Both aircraft had experienced pilots on board. The examiner in JQF and instructor in AEM were both highly experienced and had conducted similar operations many times before. The student in AEM had a high level of experience as a VFR pilot operating in controlled and non-controlled airspace. The exam candidate in JQF had completed an intense period of training and been assessed as competent to undertake the final assessment for their training course. All the pilots were familiar with the operational environment and how to separate from other traffic.

Both aircraft had operational requirements that needed to be achieved. According to the published approach chart, and the pilots interpretation of the ERSA requirements, AEM had to be at an altitude of not below 3,900 ft passing overhead Mangalore Airport to conduct the planned approach. Vertically, JQF had to avoid terrain until above 3,400 ft within 10 NM of the airport, and laterally, JQF had to be established on the outbound track to waypoint LACEY within 5 NM of the departure airport. If the intercept of the outbound track exceeded this distance, the candidate would not have demonstrated the required competencies for the departure sequence of the flight test. In controlled airspace these flight tracking requirements would be assessed and managed by an air traffic controller. In non-controlled airspace the pilots' were required to assess and manage the operational requirements and collision risk.

AEM and JQF were both fitted with dual radios. Examination of the radios fitted to JQF identified that the radios were tuned to the expected CTAF and Melbourne Centre frequencies. As the pilots of AEM had not indicated to the controller that they were switching to the CTAF, it can also be reasonably assumed that they also had the radios tuned to the appropriate CTAF and Melbourne Centre frequencies.

Air traffic control recordings confirmed that pilots from both aircraft communicated with Melbourne Centre, and interviews with other pilots in the area identified calls occurring from pilots of both aircraft on the CTAF. Significantly, a review of events leading up to the collision identified that pilots from AEM and JQF may have been communicating on different frequencies at the same time and therefore missed important alerting information from, and about, the other aircraft.

The human ability to monitor two frequencies simultaneously is limited, particularly in periods of high workload or stress, such as during a flight test or early instrument flight, and when there are other non-pertinent broadcasts on the frequencies. While the instructor in AEM and the examiner in JQF had more capacity to monitor both frequencies than the students by virtue of their relative experience, they both had other responsibilities in their training and checking roles that may have affected their ability to identify and assess all broadcasts. The initially missed call made from the Melbourne Centre controller to the pilots of AEM, where the pilots were likely either listening to the AWIS or setting up the aircraft for the descent to the approach is consistent with the known effect of workload on other tasks.

While other pilots flying in the area recalled broadcasts from both aircraft on the CTAF prior to the accident, no-one recalled coordinating transmissions between the pilots of the two aircraft. While it is possible that this may have occurred and not been recalled by other pilots in the area, this was considered unlikely.

Having both been advised of the presence of the other by the Melbourne Centre controller, it is also highly unlikely that the pilots intentionally continued into a situation where they assessed the other aircraft to be a threat without taking action, including communicating, to protect themselves. As such, the ATSB concluded that the pilots either failed to identify that a collision risk existed or identified the potential risk but incorrectly assessed that the aircraft were sufficiently separated. In either case, the primary defence of established self-separation required in non-controlled airspace was absent.

Limitations of see-and-avoid

While it is not certain that the accident took place in cloud, it is clear the accident took place in instrument meteorological conditions due to the presence of extensive cloud. It is likely that AEM was in cloud for most of its descent from 6,000ft. JQF may have manoeuvred around cloud during the climb, explaining the variation in track, or passed through cloud on its climb, and had cloud between it and AEM for most of the time from when traffic information was passed until the collision.

This would have significantly reduced the likelihood that the aircraft were visible to one another prior to the collision. If either aircraft were operating in cloud, see-and-avoid would have been unachievable to both. However, if visual meteorological conditions had existed, under IFR, they would have been expected to use see-and-avoid, along with radio broadcasts, to avoid each other.

The limitations of see-and-avoid have been widely discussed in previous accident investigations, and in CASA guidance to pilots.

After JQF entered a turn towards the outbound track, the two aircraft maintained a reasonably constant relative position. This means that, had they been visible to each other, their position in the windscreen would have had limited movement, making perception difficult. The closure rate between the two aircraft was also very high, meaning that even 20 seconds prior to the collision, the angular size of each aircraft would have made them barely perceivable. Other factors that may have affected the ability of the pilots to see and avoid conflicting traffic included:

- The crew of AEM were not directly alerted to the direction and height of JQF once airborne and may have either believed JQF was right of their track from the information in the associated departure call. Equally, they may have not heard JQF's departure call through making their own report to Melbourne centre or inbound CTAF broadcast at the same time, and therefore not realised JQF was airborne.
- The aircraft were both white with a background of textured ground or cloud.

The lack of variation in the flight tracks prior to the mid-air collision strongly suggests that the pilots did not see the other aircraft in time to commence avoiding action.

Local procedures

The evidence supports the pilots in the two aircraft probably having different interpretations of the wording of the local altitude requirements for practice instrument approaches at Mangalore detailed in the En-Route Supplement Australia (ERSA). It is also known that these different interpretations were held and applied by pilots other than those involved in this accident.

The different interpretations affected the altitude that AEM was required to be at when overhead the VOR. According to the reported understanding of the pilots in AEM, the approach would be flown as published, passing overhead the VOR at 3,900 ft and terminating the approach 1,000 ft higher than the minima. However, using the reported understanding of the pilots in JQF, aircraft conducting a practice VOR approach at Mangalore would start the approach at 4,900 ft. While it is not possible to determine why the pilots of JQF levelled off briefly at 4,100 ft prior to the collision, one possible consideration is that they may have believed they were passing a safe distance below AEM on its inbound descent to the VOR.

While the controller provided traffic information to the pilots of JQF that AEM was descending for airwork to 'not above 4,000 ft', the information that AEM was at 5,000 ft when the traffic information was passed, combined with possibly not hearing any inbound call from AEM, may have supported the pilots of JQF's mental model of the higher practice approach height being used.

The safety benefit of clearly worded standard operating procedures, applied in the same way by all, is clearly understood in aviation. The procedure was originally written to separate IFR traffic from circuit traffic, which both interpretations would achieve. The risk of misunderstanding this procedure was identified by the CASA Office of Airspace Regulation at Ballarat in 2017. Despite that, the written procedure remained unchanged at Ballarat, Mangalore and two other airports. Information in the ERSA is published by Airservices, based on information provided by the airport operator. CASA advised that the procedure was intended to be applied by adding 1,000 ft to all heights in the approach.

Traffic information

From the Melbourne Centre records, ADS-B data, and the estimated times of broadcasts on the CTAF, it appears that there was some overlap between the pilots of the two aircraft making key transmissions or actions on different radio frequencies at the same time. In particular, around 1119 – 1121 the crew of AEM were likely checking the AWIS and communicating with the Melbourne Centre controller at the top of their descent and receiving traffic information. During the same time period, the pilot under examination in JQF was probably broadcasting on the CTAF prior to take-off.

This may have affected pilot awareness of the position of the other aircraft, and the associated collision risk.

The controller provided traffic information to each aircraft in accordance with the required procedures. The content of the traffic information gave the pilot of each aircraft the position of the other aircraft at the time, and the intended flight path. However, the timing of the traffic information did not give the pilots in AEM in particular, a clear understanding of where JQF would be as their flight paths neared.

AEM was outside the Melbourne Centre controller's airspace and on a different frequency when the pilot of JQF made their taxi call. When AEM was given traffic about JQF, it was reported that JQF was still on the ground, shortly to depart. Analysis of ADS-B data available after the accident, which was not available to the controller at the time, indicated it was likely that JQF was somewhere in the take-off sequence at this time, but had not yet appeared on the controller's display.

It is possible that JQF made a rolling broadcast, reportedly heard by other pilots in the CTAF, at the time that the pilots of AEM were providing information to the Melbourne Centre controller about their descent and airwork, or listening to the AWIS. If this were the case, the pilots of AEM may have been waiting to hear a broadcast from JQF on the CTAF indicating their take-off, and not expecting that they were airborne already. This, combined with the absence of JQF on the electronic flight bag display of the student in AEM, and the higher workload environment that would be expected in training a first VOR approach, made it unlikely that they had updated their mental model that JQF had departed and were a potential threat.

At the time the pilots of JQF were passed traffic about AEM, AEM was 10-11 NM from Mangalore. Previous students of the instructor have advised they were taught to provide traffic information early, at about 15 NM rather than the minimum required 10 NM. This was a recommended procedure due to the high performance of the Travel Air, but also meant that it was likely that AEM made a CTAF broadcast sometime in the window that the pilots of JQF were in the initial climb, changing radio frequencies to Melbourne Centre, or actively making the departure report to the Melbourne Centre controller.

If the pilots of AEM had made their CTAF broadcast later in the window, closer to 10 NM, which is possible considering the workload for the student setting up and conducting their first VOR approach, it is possible that the CTAF broadcast from AEM and the Melbourne Centre report from the crew of JQF were made at the same time, with neither aircraft occupants hearing the other.

Alternatively, the pilots of AEM may have heard the Melbourne Centre departure report made by the pilot of JQF, but, due to the missing ‘tracking to’ information in the call, expected that JQF was to the right of their track and not a threat to their inbound descent.

In summary, while there were a number of factors that may have impeded radio communication between the pilots of the two aircraft, it could not be determined why there was no apparent coordination on the CTAF.

There were opportunities for the traffic information to have been passed by the controller to each aircraft earlier, although the pilots of AEM would still have been told JQF was on the ground and the crew of JQF would have been told that AEM was inbound, but over 15 minutes away at the time of the JQF taxi call. As such, the earlier provision of traffic information would probably not have changed the alerting it provided. There is potential however, that traffic information provided to the pilots of JQF while they were still on the ground after their initial taxi call, but prior to departure, could have led to the aircraft remaining on the ground until AEM was overhead the airport.

Air traffic control procedures have no requirement for a controller responsible for Class G airspace to provide updated traffic information to IFR aircraft. Analysis conducted for the ATSB by an air traffic services subject matter expert identified a number of potential reasons why updated traffic information would not have been provided. Specifically, the controller:

- could reasonably expect the occupants of the aircraft were talking to each other and taking action to avoid each other
- may over-transmit the pilots while they are trying to talk to each other
- not being fully aware of any coordination between the occupants of the two aircraft, could give advice that created a hazardous situation.

Automatic dependent surveillance broadcast

When automatic dependent surveillance broadcast (ADS-B) equipment became mandatory for IFR aircraft, there was no requirement to be fitted with ADS-B receiving equipment. Had each aircraft been fitted with ADS-B IN, and a suitable cockpit display, the occupants would have received the same quality of surveillance information received by the controller.

This technology could have prevented this accident from occurring and, more generally, it provides a valuable enhancement to the long-established procedures for maintaining separation in non-controlled airspace.

Instead of receiving one snapshot of traffic information from a controller in non-controlled airspace, an ADS-B display in the aircraft constantly updates a pilot about the position of other ADS-B-equipped aircraft, and is capable of providing alerts when the traffic come within an unsafe proximity. If the pilots had more information about their proximity, either through updated traffic information or ADS-B IN display and alerts, they would probably have acted differently to separate, and avoided the collision.

Surveillance service technology has aided the work of air traffic controllers, enabling them to provide a traffic position service with known accuracy of aircraft altitude and position rather than simply applying procedural separation.

This accident occurred in a location where both SSR and ADS-B data was captured and a surveillance service was offered. In areas where an existing SSR service exists, the mandatory fitment of ADS-B broadcasting equipment, without the fitment of ADS-B receiving equipment and an in-cockpit display of traffic information has provided little advantage to operators of IFR aircraft in non-controlled airspace.

Arguably, if these two aircraft were operating outside a surveillance service, the traffic information provided to them based on AIP GEN 3.3 paragraph 2.16.4, in the AIP version dated 7 November 2019, current at the time of the accident standards, would have kept them further apart than when their positions were accurately known. So, while the controller had better traffic information and a more accurate picture of where the two aircraft were coming together, the pilots did not share this information.

The advantage of ADS-B broadcast equipment comes from extending the area in which a surveillance service can be offered to an operating aircraft, as well as providing direct information to aircraft fitted with receiving equipment both within and outside of a surveillance environment.

ADS-B IN and OUT also provide valuable alerting to VFR aircraft. CASA Advisory Circular 91-23 (2020) stated, in relation to ADS-B options for VFR aircraft, that:

> All instrument flight rules aircraft have ADS-B transmitting equipment (ADS-B OUT). Logically, ADS-B OUT is the ideal way for VFR aircraft to signal their presence directly to other aircraft. In effect, ADS-B turns the 'see and avoid' concept into 'see, BE SEEN, and avoid'.

In the lead up to the collision, all four pilots had to make decisions about the location of the other aircraft, based on information supplied to them by the controller. It is difficult for pilots to keep an updated mental model of where other aircraft are, particularly if they are not familiar with the performance capability of that particular aircraft, as they manoeuvre their own aircraft in the airspace.

By contrast, ADS-B IN equipment has the benefit of identifying accurate positions of other aircraft broadcasting ADS-B OUT information, although it still has the limitation that it cannot display other aircraft not broadcasting ADS-B OUT. Consequently, even with ADS-B IN display equipment, pilots need to be aware of positional information about potentially conflicting not broadcasting ADS-B aircraft, and not just rely on alerts generated by the ADS-B IN equipment. The NTSB report into the 2019 Ketchikan, Alaska mid-air collision, in which both aircraft were carrying ADS-B IN display equipment, showed there were limitations in alerting functions due to software differences. As such, even when ADS-B receiving equipment is fitted, radio communications should remain the primary method for pilots operating in non-controlled airspace to arrange separation with other pilots in the vicinity.

The student pilot in AEM made a proactive choice to carry an electronic flight bag (EFB), connected to a mobile network. While this EFB had the ability to display conflicting traffic, there were limitations in the type of traffic that would be displayed, and in this case it was unlikely to have displayed JQF. Tablets can however be fitted with an external ADS-B receiving unit that will provide this additional information, and in some cases aural alerting, from ADS-B broadcasting aircraft.

Short term conflict alert

Once a controller passes traffic information to two IFR aircraft, they do not receive any feedback on whether the two aircraft have established communications or a separation plan. There is no requirement for a pilot to respond that they have traffic sighted or contacted. Once traffic is passed, the controller operates on the expectation that, if required, the pilots will coordinate to ensure separation.

Because aircraft operate in non-controlled airspace, without published separation standards, it is not unusual for controllers to receive a short term conflict alerts (STCAs). Nuisance alerts, or alerts which need to be checked but very rarely responded to are of little benefit. Controllers responsible for the same airspace reported regularly receiving STCAs, with this accident being the first collision involving IFR aircraft.

These were not the only two aircraft the controller was managing at the time. While it was not reported to be a high workload period, the controller was constantly communicating with other aircraft in the time between providing traffic to the pilots of JQF and the accident. There is guidance that a STCA alert should be responded to over all other communications, and records show that the controller did prioritise an assessment of the alert while talking to another aircraft.

In the documented procedures for a STCA, there was no written difference for response to a STCA in controlled airspace and non-controlled airspace. Controllers are taught to use their judgement in assessing the integrity of a STCA and to respond appropriately. Therefore, in non-controlled airspace, when the controller is displayed a STCA, they assess the risk in the context of whether traffic information has been passed from the controller to each of the pilots of the involved aircraft. Additionally, Airservices do not consider the STCA as a defence in non-controlled airspace.

In the 3 minutes before the collision, the controller received three separate STCAs involving these two aircraft. One was spurious and the velocity vectors at the time of the others projected the aircraft would pass each other, albeit narrowly for the third alert. The recordings indicated that the controller responded to these as per procedures.

With hindsight, the velocity vectors during the third STCA, which occurred less than 30 seconds prior to the collision, accurately indicated the conflict. When the STCA was assessed and acknowledged by the controller about 10 seconds prior to the collision, the display indicated that 500 ft displacement existed between the two aircraft, which the controller considered to be a reasonable pilot-managed vertical separation. However, taking into account the filtering of data, and the permitted 200 ft tolerances, the risk of collision was higher that indicated on the display.

Additionally, this information was presented in the context that:

- alerts regularly occurred as nuisance or no-risk alerts
- alerts were based on separation standards not appropriate to the airspace
- traffic had been provided to the aircraft in accordance with procedures
- the aircraft still appeared vertically separated
- self-separation permitted the two aircraft to pass relatively closely.

It is acknowledged that the final STCA activation provided limited time for the controller to react and broadcast a safety alert or suggested avoiding action.

However, given typical reaction times, the ATSB determined that 30 seconds was sufficient time to assess the final STCA, provide a safety broadcast and probably prevent the collision. Equally, given the same reaction time considerations, it is questionable whether a controller radio broadcast, 10 seconds prior to the collision could have been processed and reacted to by the pilots sufficiently to have manoeuvred the aircraft to prevent the accident.

Airspace

When operating in non-controlled airspace (such as the current Class G airspace around Mangalore), whether under the instrument or visual flight rules, pilots hold responsibility for separation from other aircraft. An ATSB review of historical occurrences identified that this was the first ever collision between aircraft operating under the instrument flight rules in Australia under a procedure that has been in place for some decades.

This record indicates that self-separation using broadcast traffic advice has been a largely reliable procedure.

The ATSB does however note that the effectiveness of the current pilot-separation method relies on individual pilots:

- recognising a potentially unsafe situation
- formulating an effective separation plan that often requires coordination with the occupants of the other involved aircraft.

This process is almost exclusively reliant on individual human actions without other mechanisms potentially acting as a safeguard and/or safety redundancy, and as such subject to human error, even when it involves experienced pilots. Furthermore, such errors often increase under high workload associated with, for example, instrument flying procedures, low experience or a busy airspace environment. Of note, the airspace surrounding Mangalore Airport is commonly utilised for training and by pilots gaining experience, especially in instrument flying.

In that context, while the available evidence in this investigation does not support a conclusion that the present self-separation system is unsafe, there is an opportunity to potentially reduce safety risk further.

The ATSB therefore supports systemic enhancements to the overall air traffic system that have been assessed by regulatory and air traffic specialists, in keeping with their obligations as providing a net overall safety increase. Key examples of such enhancements include:

- the increased use of controlled airspace and ADS-B aircraft surveillance data (both by air traffic services and in-cockpit)
- improved monitoring of air traffic movements (both quantity and complexity) to assist the identification of increasing risk areas.

With respect to the accident involving VH-JQF and VH-AEM, had the aircraft been operating in controlled airspace (an example being Class E airspace) they would have been positively separated and therefore the collision would have been unlikely to have occurred.

Findings

ATSB investigation report findings focus on safety factors (that is, events and conditions that increase risk). Safety factors include 'contributing factors' and 'other factors that increased risk' (that is, factors that did not meet the definition of a contributing factor for this occurrence but were still considered important to include in the report for the purpose of increasing awareness and enhancing safety). In addition 'other findings' may be included to provide important information about topics other than safety factors.

Safety issues are highlighted in bold to emphasise their importance. A safety issue is a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operating environment at a specific point in time.

These findings should not be read as apportioning blame or liability to any particular organisation or individual.

From the evidence available, the following findings are made with respect to the mid-air collision and subsequent collision with terrain involving Piper PA44-180 Seminole, VH-JQF and Beech D95A Travel Air, VH-AEM, near Mangalore Airport, Victoria, on 19 February 2020.

Contributing factors

- Following receipt of verbal traffic information, the pilots did not successfully manoeuvre or establish direct communications on the common traffic advisory frequency to maintain separation, probably due to the collision risk not being recognised.
- While it is probable that the aircraft were in instrument meteorological conditions, and could not visually separate to avoid the collision; the known limitations of the see-and-avoid principle meant that the pilots were unlikely to have seen each other in sufficient time to prevent the collision even in visual conditions.
- Following receipt of a short term conflict alert, the controller assessed it in accordance with the required procedure. After considering that the pilots had been passed mutual traffic information and were required to ensure their own separation in non-controlled airspace, the controller did not intervene further.
- While the pilots were responsible for self-separation within the Mangalore common traffic advisory frequency area, they did not have access to the same surveillance data, including automatic dependant surveillance broadcast information available to air traffic control. As a result, the pilots were required to make timely decisions to avoid a collision without the best available information.

Other factors that increased risk

- **The En-Route Supplement Australia included a requirement to add 1,000 ft to the prescribed practice instrument approach 'altitude' at Mangalore Airport. The procedure did not detail whether this height was to be applied to the minimum descent altitude or to all approach altitudes, resulting in varied application and an increased risk of traffic conflicts. (Safety issue)**

Safety issues and actions

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues. The ATSB expects relevant organisations will address all safety issues an investigation identifies.

Depending on the level of risk of a safety issue, the extent of corrective action taken by the relevant organisation(s), or the desirability of directing a broad safety message to the aviation industry, the ATSB may issue a formal safety recommendation or safety advisory notice as part of the final report.

All of the directly involved parties were provided with a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

The initial public version of these safety issues and actions are provided separately on the ATSB website, to facilitate monitoring by interested parties. Where relevant, the safety issues and actions will be updated on the ATSB website as further information about safety action comes to hand.

ERSA procedure

Safety issue description

The En-Route Supplement Australia included a requirement to add 1,000 ft to the prescribed practice instrument approach 'altitude' at Mangalore Airport. The procedure did not detail whether this height was to be applied to the minimum descent altitude or to all approach altitudes, resulting in varied application and an increased risk of traffic conflicts. (Safety issue)

Issue number:	AO-2020-012-SI-01
Issue owner:	Civil Aviation Safety Authority
Transport function:	Aviation: General aviation
Current issue status:	Open – Safety action pending.
Issue status justification:	To be advised

Response by CASA

CASA is reviewing the entries in AIP-ERSA for Mangalore as well as Ballarat, Busselton and Latrobe Valley for conducting training on NDB, VOR and RNP approaches to determine if it is appropriate to add 1,000 ft to all of the procedure altitudes. This may result in the removal of these published training procedures. If this is the case then CASA undertakes to engage with all flying schools and organisations that conduct this type of training prior to their removal from the AIPERSA.

ATSB comment

The ATSB notes that the AIP-ERSA requirement for Mangalore has been in place for a considerable period of time and is concerned about the indefinite nature of the proposed evaluation and other associated activities to address the safety issue.

As a result, the ATSB has issued the following safety recommendation.

Safety recommendation to the Civil Aviation Safety Authority

The ATSB makes a formal safety recommendation, either during or at the end of an investigation, based on the level of risk associated with a safety issue and the extent of corrective action already undertaken. Rather than being prescriptive about the form of corrective action to be taken, the recommendation focuses on the safety issue of concern. It is a matter for the responsible organisation to assess the costs and benefits of any particular method of addressing a safety issue.

Recommendation number:	AO-2020-012-SR-06
Responsible organisation:	Civil Aviation Safety Authority
Recommendation status:	Released

The Australian Transport Safety Bureau recommends that the Civil Aviation Safety Authority addresses the ambiguity in the En-Route Supplement Australia requirement relating to practice instrument approach altitudes at Mangalore Airport to reduce the variation in application and risk of traffic conflicts.

Safety action not associated with an identified safety issue

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. All of the directly involved parties are invited to provide submissions to this draft report. As part of that process, each organisation is asked to communicate what safety actions, if any, they have carried out to reduce the risk associated with this type of occurrences in the future. The ATSB has so far been advised of the following proactive safety action in response to this occurrence.

Safety action by the Civil Aviation Safety Authority

The Civil Aviation Safety Authority is conducting a study of the airspace within a 25 NM area of Mangalore Airport from the ground to 8,500 ft AMSL. The study will evaluate the suitability of the airspace, including efficient use, equitable access for all users, appropriateness of the airspace classification and the existing services and facilities provided by the air navigation service provider. At the time of publication this study has not been published.

Safety action by Airservices Australia

Airservices Australia has submitted a proposal to the Civil Aviation Safety Authority for the implementation of a surveillance flight information service (SFIS) at Mangalore Airport, however the review process for the SFIS is pending the completion of the Office of Airspace Regulation study of the airspace surrounding Mangalore Airport. In the interim period a Melbourne Centre controller is monitoring the CTAF frequency during prescribed hours to provide a safety alerting service if required.

Airservices Australia has also raised a consultation to lower the base of Class E airspace around Mangalore Airport. At the time of writing that proposal was in review by Airservices following an industry consultation period.

General details

Occurrence details

Date and time:	19 February 2020 1124 EDT	
Occurrence category:	Accident	
Primary occurrence type:	Airborne collision	
Location:	Mangalore Airport, Victoria	
	Latitude:36° 56.294' S	Longitude:145° 12.080' E

Aircraft details

Manufacturer and model:	Beech Aircraft Corp 95	
Registration:	VH-AEM	
Operator:	Peninsula Aero Club	
Serial number:	TD-682	
Type of operation:	Flying Training - Training Dual	
Activity:	General aviation - Instructional Flying - Instructional flying - dual	
Departure:	Tyabb, Victoria	
Destination:	Mangalore, Victoria	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 2	Passengers – 0
Aircraft damage:	Destroyed	

Manufacturer and model:	Piper Aircraft Corp PA-44	
Registration:	VH-JQF	
Operator:	Moorabbin Aviation Services Pty Ltd	
Serial number:	44-7995291	
Type of operation:	Flying Training - Training Dual	
Activity:	General aviation - Instructional Flying - Instructional flying - dual	
Departure:	Mangalore, Victoria	
Destination:	Mangalore, Victoria	
Persons on board:	Crew – 2	Passengers – 0
Injuries:	Crew – 2	Passengers – 0
Aircraft damage:	Destroyed	

Glossary

ACAS	Airborne collision avoidance system
ADS-B	Automatic Dependent Surveillance Broadcast
AIP	Aeronautical Information Publication
AMSL	Above mean sea level
AFRU	Aerodrome frequency response unit
ASD	Air Situation Display
ATC	Air traffic control
ATS	Air traffic services
ATSB	Australian Transport Safety Bureau
AWIS	Automated weather information system
AWS	Automatic weather service
BoM	Bureau of Meteorology
CASA	Civil Aviation Safety Authority
CASR	Civil Aviation Safety Regulations
CDTI	Cockpit display of traffic information
CTAF	Common traffic advisory frequency
DOK	Dookie (sector of airspace)
EFB	Electronic flight bag
ERSA	En-Route Supplement Australia
FIS	Flight information service
GAF	Graphical Area Forecast
GNSS	Global navigation satellite system
HUM	Hume (sector of airspace)
ICAO	International Civil Aviation Organization
IFR	Instrument flight rules
ILS	Instrument landing system
MATS	Manual of Air Traffic Services
MOS	Manual of Standards
NDB	Non-directional beacon
NAPM	National ATS procedures manual
NM	Nautical mile
OVN	Ovens (sector of airspace)
QNH	That pressure setting, which, when placed on the pressure setting sub-scale of a sensitive altimeter of an aircraft located at the reference point of an aerodrome, will cause the altimeter to indicate the vertical displacement of the reference point above mean sea level

SAR	Search and rescue
SFIS	Surveillance flight information service
SME	Subject matter expert
STCA	Short term conflict alert
TAF	Terminal area forecast
TCAS	Traffic collision avoidance system
VOR	VHF Omni-directional range

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- operators of VH-AEM and VH-JQF
- aircraft owner of VH-AEM
- air traffic controller
- Civil Aviation Safety Authority
- Airservices Australia
- Bureau of Meteorology
- Victoria Police
- next of kin
- witnesses
- AvPlan
- air traffic control subject matter expert

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Submissions

Under section 26 of the *Transport Safety Investigation Act 2003*, the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. That section allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the following directly involved parties:

- the operators of VH-AEM and VH-JQF
- the owner of VH-AEM
- the air traffic controller
- Airservices Australia
- air traffic control subject matter expert
- Bureau of Meteorology
- Civil Aviation Safety Authority
- AvPlan
- United States National Transportation Safety Board
- Office of the Aircraft Accident and Incident Investigation Commission, Thailand

Submissions were received from:

- the operators of VH-AEM and VH-JQF
- the air traffic controller
- Airservices Australia
- Bureau of Meteorology
- Civil Aviation Safety Authority
- Office of the Aircraft Accident and Incident Investigation Commission, Thailand

Appendix

Appendix A - Sequence of events

The sequence of events shows the key events identified in the report, including a transcript of the radio calls recorded between the Melbourne Centre controller and the pilots of AEM and JQF (in italics). The transcript does not include all calls made between the Melbourne Centre controller and other pilots or controllers.

Time start (* indicates approximate time)	**Time end (* indicates approximate time)**	**Aircraft**	**Comment**
1055*			Departure of AEM from Tyabb
1111:21	1111:32	JQF	*Melbourne Centre, JQF is two POB IFR Mangalore taxying for runway two three for Mangalore*
		Melbourne Centre	*JQF, Melbourne Centre, G'day. Squawk three six two four, there's no reported IFR traffic.*
		JQF	*Three six two four, JQF*
			Coordination to Melbourne Centre controller of AEM. Aircraft had previously reported estimating Mangalore at 1126.
1117:42	1117:55	AEM	*Melbourne Centre, AEM, maintaining six thousand.*
		Melbourne Centre	*AEM, G'day Melbourne Centre. Area QNH one zero one zero, and there's no reported IFR traffic for your descent for your airwork at Mangalore.*
		AEM	*One zero one zero, not traffic for airwork at Mangalore, thank you, AEM.*
1118:22			AEM entered ML Centre airspace (30 DME boundary)
1119:35	1119:54	AEM	*AEM, leaving six thousand for airwork four thousand down to ground, will call again time five zero or on departure.*
		Melbourne Centre	*AEM thanks, I'll talk to you again by time five zero and no reported IFR traffic for not above four thousand.*
		AEM	*AEM*
1120:07	11:20:08	Melbourne Centre	*AEM, actually I will pass you some traffic when you're ready.*
1120:15	1120:28	Melbourne Centre	*AEM, Centre?*
		AEM	*AEM go ahead*
		Melbourne Centre	*AEM shortly to depart Mangalore southbound, or via LACEY is JQF, a Seminole, they'll be on climb to seven thousand*
		AEM	*JQF copied, AEM.*

1120:31			JQF first appeared on controller's display
1122:19	1123:00	JQF	*Melbourne Centre, JQF departure*
		Melbourne Centre	*JQF's identified, verify level with departure*
		JQF	*JQF departure at Mangalore two three passing two thousand seven hundred on climb to seven thousand tracking to LACEY, Mangalore*
		Melbourne Centre	*JQF area QNH one zero one zero*
		JQF	*One zero one zero, JQF*
		Melbourne Centre	*And JQF, traffic six miles in your twelve o'clock is AEM, a kingair, they're inbound to Mangalore for airwork, passing five thousand, on descent to not above four thousand*
		JQF	*Copy traffic JQF*
1122:42			First STCA - between JQF and other traffic (during calls listed above)
1122:49			Second STCA – between JQF and AEM. Occurred as Melbourne Centre controller was providing traffic to the pilots of JQF (above)
1123:51	11:24:09		Third STCA appeared on controller display. Was assessed and acknowledged
1124:16			Last updated data point displayed to controller prior to collision.
1124:20			Approximate time of collision