From see-and-avoid to detect-and-avoid: Learnings from a mid-air collision investigation

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Introduction

On 19 February 2020, Australia had its first civilian instrument flight rules (IFR) mid-air collision.

Around 1124, approximately 8 nautical miles south of Mangalore Airport, in central Victoria, a Beechcraft D95A Travel Air and a Piper PA-44 Seminole collided at approximately 4,100 ft above ground level. The Travel Air, registered VH-AEM, was conducting an instrument flight rules training flight, approaching Mangalore from the south for a practice instrument approach, with an instrument rating student and instructor on board. The Seminole, registered VH-JQF, was departing Mangalore to the south, for an instrument flight rules examination flight with a pilot under examination and an examiner on board. Following the collision, both aircraft collided with terrain and all four pilots were fatally injured.

The investigation found no technical failures with either aircraft that would have existed prior to the collision, and that both were fitted with all the equipment required for IFR flight. The collision occurred in non-controlled airspace, where the aircraft were being provided a traffic information service by an air traffic controller, but not a separation service. The pilots were responsible for broadcasting on the Mangalore Airport radio frequency to arrange their own separation.

The work completed for this investigation was published in two reports:

- AO-2020-012 – 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

- AS-2022-001 – Aircraft performance and cockpit visibility study supporting investigation into the mid-air collision involving VH-AEM and VH-JQF near Mangalore Airport, Victoria on 19 February 2020.

Among the findings, the Australian Transport Safety Bureau (ATSB) investigation found that while the pilots of the two aircraft received traffic information about one another, the pilots did not successfully manoeuvre or establish direct communications, probably due to the collision risk not being recognised. After this point, the pilots had to rely on the see-and-avoid principle as a last defence to avoid collision, despite likely being in instrument meteorological conditions.

This led investigators to three key questions.

1. How do four pilots, with between 250 and 21,000 hours, all experienced with local operations, not recognise the collision risk posed?
2. Could 'see-and-avoid' have been effective in the accident conditions, or if conditions had been more favourable to visual acquisition?
3. What other technologies exist that could have assisted these pilots to in identifying the threat from the other aircraft?

The pilot mental model

As pilots fly, they develop a picture, or mental model, of their surroundings. When pilots have access to current, accurate information, they have the best opportunity to improve their mental model of the situation around them. It is not possible to determine exactly what the pilots were thinking, or what was occurring in either aircraft prior to the accident. However, factors including weather, workload, operational requirements, local procedures and communication all likely played a part in affecting each of the four pilot's understanding of their surrounds in a different way.

The ATSB investigation reviewed a range of data related to the weather at the time of the accident, to determine the conditions that the aircraft were operating in. Based on this information it was determined that it was likely that the aircraft were operating in instrument meteorological conditions (IMC) at the time of the collision.

One effect on a pilot's mental model of operating in IMC may include the expectation of fewer aircraft operating in the vicinity of the airport due to visual flight rules pilots not being able to fly. Additionally, as the pilots are flying with reference to instruments, they likely have their focus inside the aircraft, more than if they were flying with visual references. This increases their reliance on procedural techniques and accurate communications to maintain separation, regardless of whether they are operating inside or outside controlled airspace.

The pilots of both aircraft had operational requirements to comply with. For their departure, the pilots climbing out of Mangalore airport had to intercept their IFR airway within 5 nautical miles of the airport, and at the same time being above the minimum sector altitude of 3,400 ft. This was also a test flight, which likely increased the stress and resulting workload for the pilot under examination during the preparation and flight. In the other aircraft, the IFR student pilot was conducting their first VOR approach in the aircraft. While the pilots had practiced this in the simulator previously, the pilot likely had a higher workload in conducting a new procedure in the aircraft than they would after gaining more experience with conducting the descent type.

While it could not be determined as contributing to the accident, an identified factor that increased risk was a local airport procedure that was known to be interpreted by pilots in different ways. The En-Route Supplement Australia (ERSA)(1) included a requirement to add 1,000 ft to the prescribed practice instrument approach ‘altitude’ at Mangalore Airport but did not detail whether this height was to be applied to the minimum descent altitude or to all approach altitudes This resulted in a varied application, with some pilots who interpreted the starting height for the VOR approach to be 4,900 ft while others interpreted it as 3,900 ft, creating an increased risk of traffic conflicts. The Civil Aviation Safety Authority (CASA) of Australia accepted the safety issue identified by the ATSB and have since modified the ERSA for this airport and three others with a similar procedure, to clarify the language and intention of the procedure.

As the two aircraft were operating in non-controlled airspace, the pilots held the responsibility for ensuring their self-separation from other aircraft. There were no set separation standard for the aircraft to adhere to, but was intended to occur via a combination of a pilot making their own procedural radio broadcasts on the Mangalore Airport common traffic advisory frequency (CTAF), interpreting radio broadcasts from other pilots. If a threat from traffic was identified the pilots would communicate directly with to arrange a separation method.

In addition to the CTAF communications, as the aircraft were operating in ‘Class G’ airspace, the pilots involved in this accident were being provided a traffic information service by air traffic control on a separate frequency about other IFR aircraft operating in the area. The intention of this service was not to provide a separation service, but rather prompt pilot awareness of other aircraft so they could make communications on the CTAF. From the recorded frequency, the investigation considered multiple factors related to the air traffic control communications and procedures that could have affected each pilot’s mental model. While traffic information was provided according to the procedures, it did not provide the pilots of either aircraft with an ongoing accurate picture of where the other aircraft was in relation to their own aircraft. The language and specific wording used by both the pilots and the controller on the recorded frequency was reviewed, and several words identified that potentially could have created confusion for the pilots of the different aircraft.

Both aircraft were fitted with 2 radios allowing the pilots to, within human limitations, monitor both the CTAF and ‘Class G’ area frequencies simultaneously. In addition, the pilots of AEM also had to change frequency to receive information from the automated weather information service prior to approach into Mangalore Airport. None of the other pilots operating on the CTAF at the time recall the pilots in the two aircraft communicating directly to each other to arrange separation, however different pilots recall different radio broadcasts made by pilots in each of the aircraft independently. This provides evidence that both sets of pilots were making calls according to procedure. While recordings of the CTAF were not available, a review of the available flight data and ATC radio recordings identified several occasions where it was considered possible that the two aircraft were broadcasting on different frequencies, and therefore potentially did not hear any updated information about the location and intentions of the other aircraft. If this was the case, then none of the pilots involved likely had an updated understanding of where the other aircraft was in relation to their own aircraft.

Despite the skills and experience of the pilots involved, it is likely that a combination of factors led to the risk not being recognised, and the collision occurring. After considering the aspects leading to this, the investigation team sought to determine what final defences in the aircraft could have given the pilots an opportunity to detect the other aircraft and communicate with them prior to the collision occurring.

See and avoid

Australian regulation CASR 91.325 states 'a flight crew member must, during a flight, maintain vigilance, so far as weather conditions permit, to see and avoid other aircraft'. Other countries have similar regulations in place.

The see and avoid principle has been discussed in many forums previously, including in the ATSB research report conducted by Hobbs (1991) Limitations of the See-and-Avoid Principle. As the pilots involved in this collision were operating in IMC, between layers of cloud and in parts potentially fully surrounded by cloud, there was limited opportunity for any of the pilots to sight the other aircraft. However, the investigation wanted to understand what the precise limitations were in this case, and whether, even if the visibility conditions had been more favourable, the pilots would have had the opportunity to see the other aircraft in sufficient time to react and avoid a collision.

The aircraft performance and cockpit visibility study

To answer this question the ATSB commenced a safety study looking at aircraft performance and cockpit visibility. This study was to assist investigators understanding how the aircraft ended up where they did and what limitations there were to effective use of 'see and avoid'.

The ATSB had not previously conducted a study of this type, so sought guidance from the National Transportation Safety Board (NTSB) of the United States, who had undertaken several similar studies following mid-air collisions. Based on the NTSB's guidance the study was carried out in 2 parts:

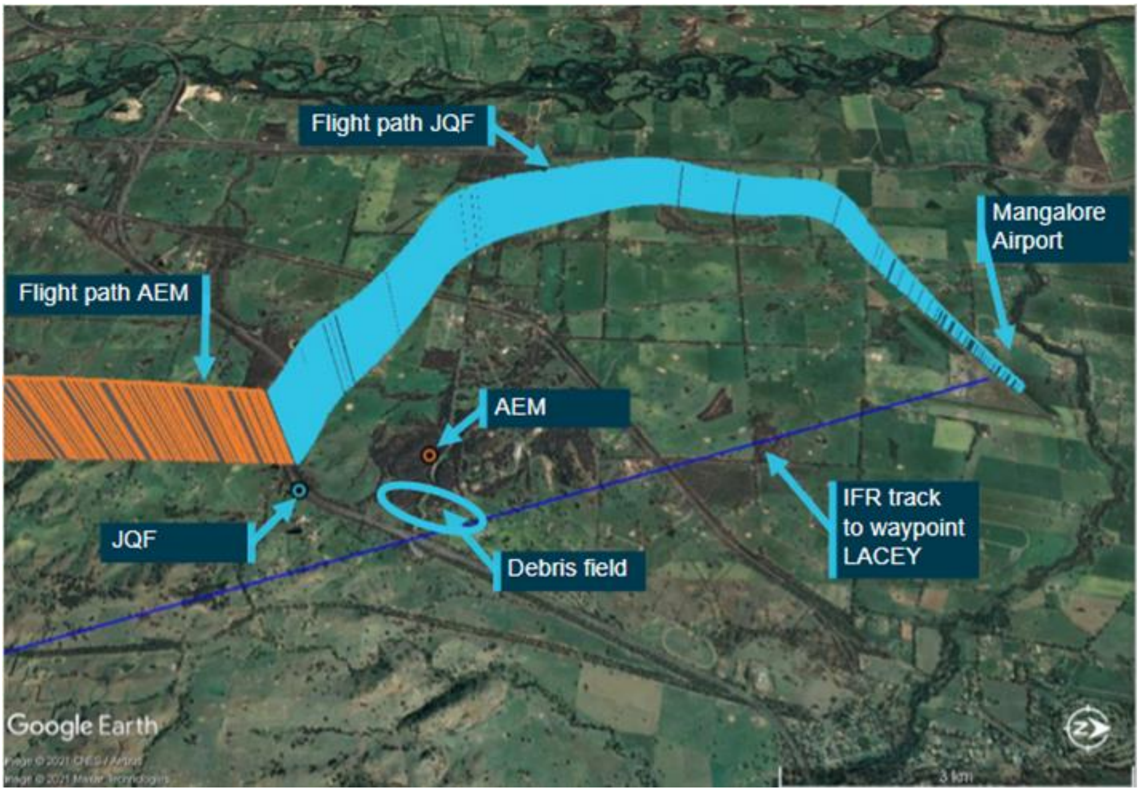
- An aircraft and pilot performance study
- A cockpit simulation intended to replicate as closely as possible what the pilots could see.

Aircraft and pilot performance study

Aircraft position

The first element in calculating aircraft visibility was to determine the relative position of each aircraft to one another. In Australia it is a requirement for aircraft operating under the IFR to broadcast Automatic Dependent Surveillance – Broadcast (ADS-B) data to assist air traffic control in locating and tracking them. The ATSB obtained these ADS-B data transmissions from each aircraft, captured at approximately 2 hertz. The flight paths for each aircraft are shown in Figure 1.

Figure 1: Flight paths of VH-AEM and VH-JQF



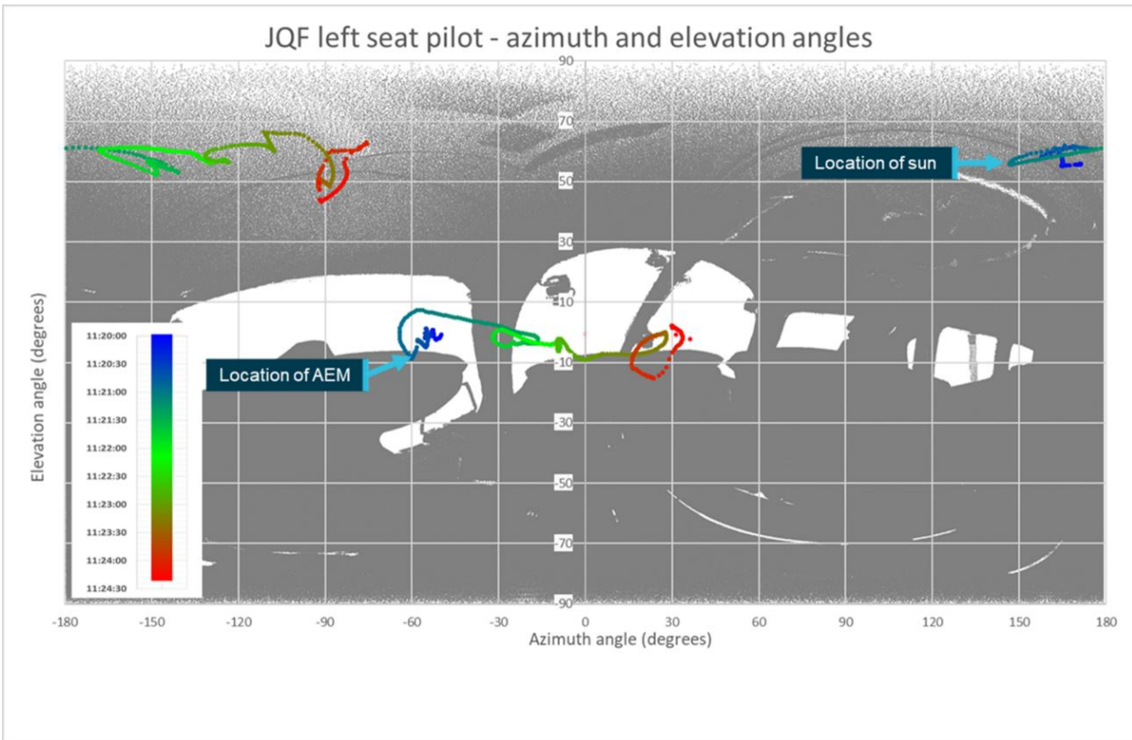
Source: Google Earth and Airservices Australia annotated by the ATSB

For analysis, the position of each aircraft depended not only on the aircraft relative positions, but also on their orientation in space. This task considered changes as each aircraft rolled and pitched in the portion of the sky visible to the pilot through the windscreen, resulting in whether the approaching aircraft was shown or hidden.

Cockpit shielding

With the relative position of each aircraft calculated, the ATSB were then able to identify parts of the cockpit that may have obstructed a pilot's view of the approaching aircraft. This was done by creating a three-dimensional point cloud model of the aircraft, built using multiple laser scans of exemplar aircraft. In this point cloud, the pilot's head and eye position were calculated. This information, combined with the calculated azimuth and elevation angles for each aircraft, laid over the cockpit view showed when the approaching aircraft was expected to be shielded by the cockpit structure. Figure 2 shows the view from the left seat pilot of JQF as AEM approaches over the final 260 seconds of the flight. The areas of grey are the areas shielded by the cockpit and the coloured dots are the position of the aircraft as it approaches over time at half second intervals.

Figure 2: Azimuth and Elevation angles of VH-AEM across the view of the left seat pilot of VH-JQF



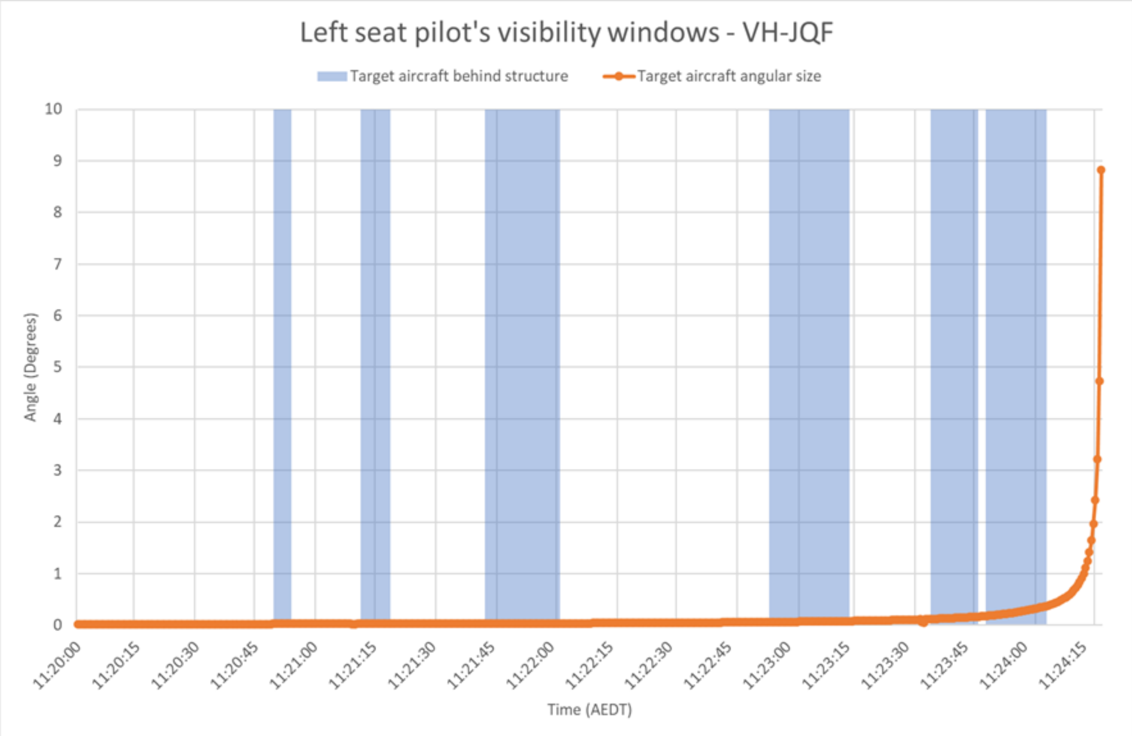
Source: ATSB

Aircraft size

For two approaching objects, the speed that an object changes in size relative to the other will depend on the size of the object that is approaching, and the speed of the approach. The calculated size for aircraft position over the final 260 seconds of flight for the left seat pilot in JQF is shown in Figure 3. Of note is the rapid increase in aircraft size to the viewer in the final seconds in the lead up to the collision.

Combining data from the calculation of the cockpit shielding and the aircraft size, investigators were able to determine not only the times when the aircraft would not have been obstructed but also the size it would have been to the viewer during these times. The question was then posed but what size does the aircraft need to be so that the viewer can perceive it and does this give the viewer to effectively react and manoeuvre the aircraft to avoid a collision.

Figure 3: Angular size and shielding windows of VH-AEM from VH-JQF



Source: ATSB

Human perception

Hobbs (1991) identified multiple factors that affect the ability to visually acquire objects during their approach, of which reaction time and object perception are key.

There was no consensus as to what the minimum perceptible size of an object may be, but in less-than-ideal conditions it was estimated to be between 0.2 and 0.6 degrees of arc in a pilot's field of view. By plotting this on the graph over the calculated aircraft size (Figure 4) gives an approximation of when the aircraft may have been visible to the pilots of both aircraft.

While the object may become visible to the pilot of one of the aircraft when it reaches that size, the pilot must notice it, and then react appropriately. Research published by the Federal Aviation Administration (FAA) of the United States in Advisory Circular AC90-48D CHG1 suggests that it takes pilots around 12.5 seconds to sight an aircraft and react effectively to it, which can be broken down into 6 stages as outlined in the table below.

Event	Seconds
See Object	0.1
Recognize Aircraft	1.0
Become Aware of Collision Course	5.0
Decision to Turn Left or Right	4.0
Muscular Reaction	0.4
Aircraft Lag Time	2.0
TOTAL	12.5

Source: Federal Aviation Administration

Theoretically this means that, with no alert or guidance, if an object on a collision course is perceived less than 12.5 seconds prior to impact then the impact will occur regardless of a pilot's attempted evasive actions.

Result

Theoretical analysis of available data and human performance information indicated that the aircraft size was on the edge of the observable range at the time needed for the pilots to react and manoeuvre the aircraft to avoid the collision. However, when considering the known weather conditions and that the pilots did not having accurate awareness of the position of the other aircraft, the chances of detection through 'see and avoid' were minimal.

The Simulation

The second part of the safety study took the analysis from the visibility study and developed a simulation to show what the pilots' views may have been in the lead up to the collision.

To develop the simulation, the ATSB sought further guidance from the NTSB. In line with the paper John O'Callaghan of the NTSB presented during the 2021 ISASI forum, the ATSB developed a tier 3 or backdrive simulation. This type of simulation was developed to give investigators the best understanding of the situation in the cockpit leading up to an accident through using aircraft flight data and performance information to effectively 'replay' a flight or portion of a flight from the pilot's perspective. This allowed investigators to see, as close as possible, through the pilot's eyes what happened. This was completed in Microsoft Flight Simulator X using the FS recorder addon to drive both the aircraft along their flight paths.

For added realism, the default cockpit in the software was replaced with known elements of the pilot's views from the visibility study, and simulated weather information to match the reported accident conditions. The cockpit views were made 30% opaque to allow for the viewer of the simulation to see where the approaching aircraft was as it moved through the shielded portions of the cockpit. The recorded area frequency radio calls were synchronised with the simulation video, with the known caveat that the pilots may not have heard all these calls due to needing to operate on two radio frequencies.

The simulation was also run modelling a cloudless, visual meteorological conditions, day to provide optimal conditions for visual acquisition.

The resulting simulation video showed the limitations of the see and avoid concept in both in the recorded conditions and better visual conditions. Considering expected human reaction times, the simulation was paused 13 seconds before the impact looking at whether the aircraft could be seen visually. It was determined that, while each aircraft may have been technically visible to the other at this point, its size and position, along with the effects of cockpit shielding, made the chances of visual acquisition for any pilots minimal.

Consideration of available technology

The limited ability for the pilots to visually acquire the approaching aircraft under both the accident and enhanced visual acquisition scenarios brought the investigative team to the final question: What technologies were available that could have improved the pilots' mental model and assisted them in determining the approaching aircraft was a threat?

The ATSB looked at 2 technologies that are available to assist in locating approaching aircraft: Aircraft collision avoidance systems (ACAS), and ADS-B IN systems.

ACAS (formerly known as traffic collision avoidance systems or TCAS) operates by interrogating another aircraft's transponder and using this information to determine if the aircraft is a threat. If it is, the system will provide multiple alerts to the pilot, escalating up to avoidance manoeuvres to prevent a collision. However, the equipment to run an ACAS is heavy and expensive and so impractical for fitment to most smaller general aviation aircraft.

The second technology the ATSB investigated was ADS-B receiving equipment, known as ADS-B IN. ADS-B IN detects ADS-B transmissions from other aircraft and unpacks them for relevant position and aircraft information. This information can then be displayed to the pilot in two ways; either through an inbuilt cockpit display of traffic information or through a supported electronic flight bag application. Electronic flight bag applications cannot receive ADS-B data on their own, but can when attached to an appropriate ADS-B receiving device, known as an electronic conspicuity device.

In addition to the display of traffic information, ADS-B IN systems may also have aural and visual alerting capabilities. When a threat aircraft breaches specific thresholds, the system will change the way that traffic is displayed to make it more visible to the pilot and provide aural alerts to draw attention to the approaching traffic. This will provide the pilot with additional critical information to assist in sighting it.

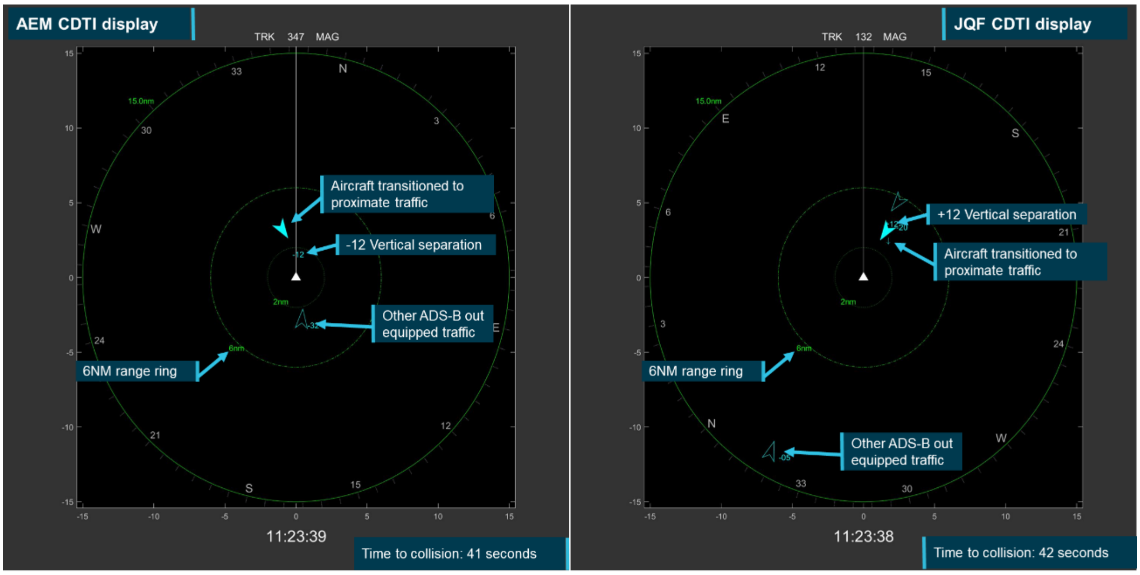
Demonstration of ADS-B IN

To examine the effectiveness of ADS-B IN technology, the ATSB developed another simulation demonstrating the information and alerts that would have been displayed to the pilots of the two aircraft involved in the accident, had they been equipped with ADS-B IN systems. The ATSB elected for the simulation to demonstrate a generic inbuilt ADS-B IN system with a cockpit display of traffic information and an aural alerting capability to most effectively show the capability of these systems, without using a particular user interface or application.

The ATSB developed the simulation using a program jointly developed by the NTSB and the RTCA, formerly the Radio Technical Commission for Aeronautics, who are responsible for standards for this technology. The simulation used ADS-B data collected for both the accident aircraft as well as for other local aircraft, to ensure that it was as realistic as possible. The resulting display showed traffic moving around the aircraft.

Figure 4 shows the simulated cockpit displays when the first visual alert is activated. The alert consists of a change from unfilled to filled cyan arrowhead for the proximal traffic. This alert is designed to draw pilot attention showing that the traffic is proximal to them but is not at this stage a threat.

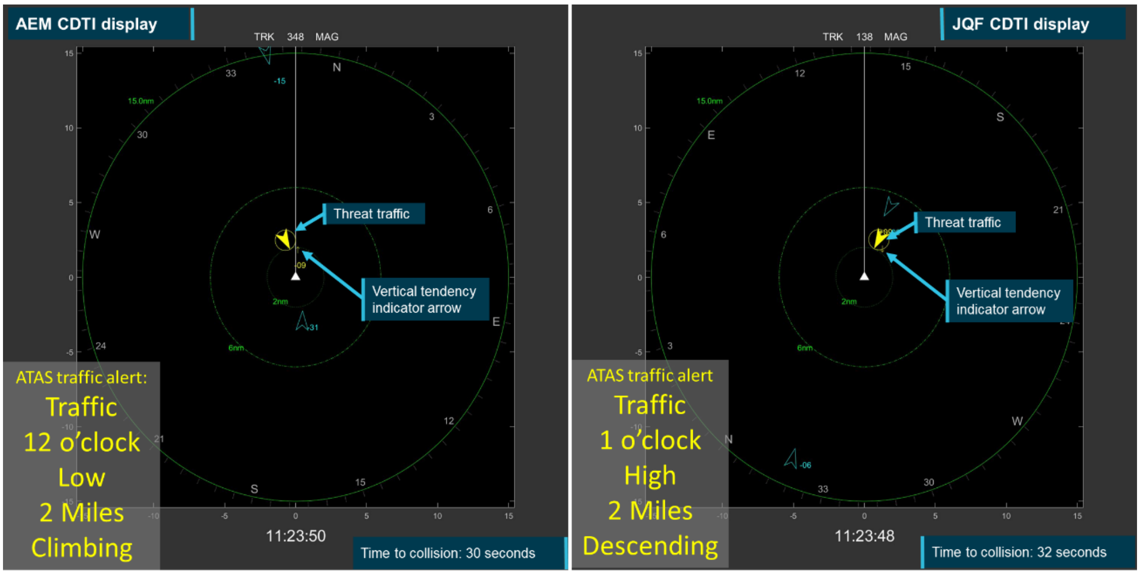
Figure 4: Simulated CDTI displays at the time of the first ADS-B IN visual alert



Source: ATSB

The second visual alert occurs when the approaching aircraft breaches what is called the 'protected airspace zone' (PAZ). This is a defined area around the approaching aircraft determined by closing speed and distance. The visual component of the alert, as shown in Figure 5, changes the marker for the approaching aircraft to a high contrast yellow and outlines it with a circle. In addition, an aural alert gives the pilot the relative bearing (in clock co-ordinates), distance to, relative vertical position, and current activity (climbing, descending or level) of the target aircraft.

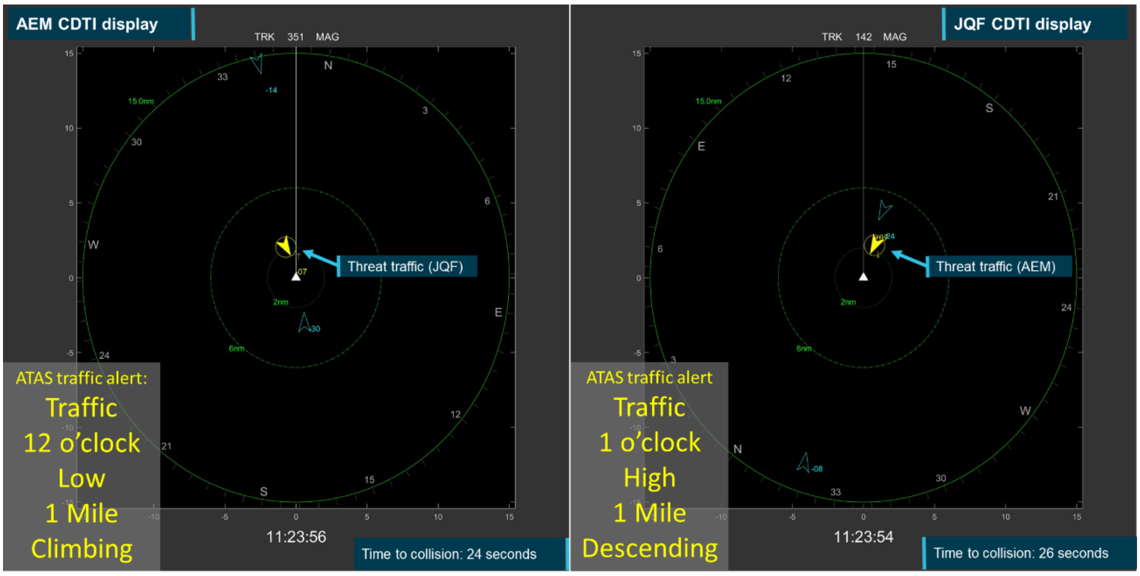
Figure 5: Simulated CDTI displays at the time of the second ADS-B IN visual alert and first aural alert



Source: ATSB

If the aircraft continue into a position within 500ft laterally and 200ft vertically, they are deemed to have entered the 'collision airspace zone' (CAZ). At this time, the system will provide the pilot with a second aural alert with updated information about the tracking and relative position of the approaching aircraft. This alert does not come with an equivalent visual alert however the approaching aircraft's arrowhead remains the high contrast yellow with surrounded by the circle. This final alert, as it would have appeared to the pilots of both aircraft, is shown in Figure 6.

Figure 6: Simulated CDTI displays at the time of the second ADS-B IN visual alert and first aural alert



Source: ATSB

In addition to the position information, within each ADS-B transmission is information about the aircraft type and its call sign or registration. This information can improve a pilot's mental model by providing more information about the traffic around them, by allowing them to match information given in a radio call with an aircraft on the visual display. From this point, a pilot can then communicate more directly and accurately with any threat aircraft. This is particularly important outside of controlled airspace or in areas where ADS-B coverage from air traffic control may be limited.

Results

The intention of the final simulation was to identify whether an ADS-B IN system could have provided the pilots of the two aircraft with more accurate information to assist them in avoiding the collision.

The simulated system provided 2 different visual and aural alerts to the pilots based on the accident conditions. The first visual alert, change to filled positional arrowhead, occurred approximately 42 seconds before the collision. This alert would be designed to draw the pilot's attention to the traffic as a potential threat. If the traffic is noticed at this time the pilot should have sufficient time to locate the other aircraft and establish communications to ensure self-separation. However, this is only a relatively minor change to the display and, if the pilot is focused outside the cockpit or on other tasks, they may not identify the change.

It was calculated that the second visual alert and accompanying aural alert would have occurred approximately 32 seconds prior to the collision. This alert, indicating the breach of PAZ, has the display change to a high contrast yellow arrowhead to draw pilot attention and make the threat aircraft more obvious on screen. Additionally, the aural alert provides information on the relative location and tracking of the target aircraft, so the pilot can look in the direction of the incoming aircraft without needing to process additional information from the display.

Finally, the aural alert for the breaching the CAZ would have occurred approximately 26 seconds before the collision.

Each of these alerts, combined with the information available from the CDTI display about aircraft type and distance, would have provided the pilots of the 2 aircraft with information about the relative location, tracking and callsign of the other aircraft long before they were likely able locate them visually. Use of this information could have updated the mental model of all four pilots giving them a better understanding of the traffic around them and the collision risk that the other aircraft posed.

Based on this analysis investigators determined that an ADS-B IN system would have provided the 4 pilots with constantly updated, accurate positional information about the other aircraft, giving them the opportunity to update their mental model, which may have affected their recognition of the threat the other aircraft posed. Ultimately, access to this additional information had the potential to have led to the collision being avoided.

Adding it to the simulation and putting it all together

To consider all information available to the investigators, the last stage of the simulation was to add two additional final elements: a moving map display showing the relative position of each aircraft to the other, and the activation of short-term conflict alerts for the air traffic controller. The investigation report contains discussion about these alerts.

The simulation is available on the ATSB website. In viewing the simulation, the ATSB has been encouraging pilots to view the animation with three questions in mind:

1. When do you first become aware that there is an approaching aircraft you need to be aware of?
2. When do you perceive that the approaching aircraft has become a threat to the extent that you would need to take action?
3. When do you visually acquire the approaching aircraft? Do you think there would have been enough time between then and the collision for you to determine it was a threat and implement an avoiding action?

Discussion of these questions has brought about a range of reactions from pilots, with most commenting that they would have been unlikely to see the aircraft with sufficient time to avoid it, but that the ADS-B IN display and alerting would have provided them with more time to establish self-separation. Subsequently the use of a system to detect the approaching aircraft rather than relying on visual acquisition provides a significantly increase opportunity for detection with appropriate time to arrange self-separate from the approaching aircraft.

Detect and Avoid

The ATSB encourages the fitment of ADS-B transmitting and receiving devices in all aircraft. The technology not only provides for enhanced situational awareness to assist in self-separation outside controlled airspace; but also provides ATC with more accurate information on aircraft movements both within and outside controlled airspace. In Australia, ADS-B data is also accessed by rescue co-ordination centres, to assist in locating aircraft accidents, particularly in remote areas; and investigative agencies including the ATSB to assist with investigations.

Currently all IFR aircraft operating within, or in and out of, Australia are required to be equipped with ADS-B transmitting equipment (ADS-B OUT). Additionally, some VFR aircraft, depending on their operational location and the type of operation, are required to be fitted with ADS-B transmitting equipment. There are currently no requirements for any aircraft operating in Australia to be equipped with ADS-B IN. There is currently no information available on the number of IFR aircraft in Australia that are fitted with ADS-B IN devices, however Australia's Civil Aviation Safety Authority (CASA) recently published data on equipment fitted in VFR aircraft including ADS-B IN. The study found that in 2020, approximately 15-18% of VFR general aviation aircraft were equipped with an ADS-B IN system.

The study also found that approximately 90% of general aviation VFR pilots use some form of electronic flight bag application (EFB) to support their operations. With the introduction of low cost electronic conspicuity devices that can both transmit and receive ADS-B information, all of these pilots can have access to up to date ADS-B information about the aircraft local to them without needing to go to the expense of a full ADS-B IN system. These devices can also provide IFR aircraft that are already equipped with ADS-B OUT, with an ADS-B IN capability. Electronic conspicuity devices capable of either ADS-B IN only or with the transmitting functionality disabled can be used in IFR aircraft to provide the pilot with ADS-B IN information without the cost of having new system installed.

While effective, these devices paired with EFB applications do not necessarily provide the full functionality of hard-wired ADS-B IN systems and must be correctly setup and configured to work effectively.

To encourage the take up of ADS-B technology both transmitting and receiving amongst VFR pilots the Australian Government opened a rebate scheme in July 2022. This scheme provided a 50% rebate, up to $5,000, on the purchase an installation of ADS-B devices for VFR aircraft. The rebate scheme included the purchase of electronic conspicuity devices to connect to electronic flight bag applications.

It must be noted that having an ADS-B IN display in an aircraft does not change a pilot's responsibility to communicate to other aircraft via the appropriate radio frequency. These systems should not be used to make traffic avoidance decisions on their own, but rather as an additional source of accurate information for pilots to use when making arrangements with other pilots.

The future

Despite the known limitations of the 'see and avoid' concept, including those demonstrated with this accident, it has been used effectively for a long time. However, the basic premise relies on the pilot of the aircraft viewing the environment around them and using radio calls to build situational awareness to identify other aircraft in the vicinity. However, the uptake of remotely piloted or uncrewed aircraft systems (RPAS or UAS) is beginning to challenge this as we are seeing more aircraft operating without a pilot onboard to use visual acquisition.

This is not a problem when the RPAS or UAS are small and operating within line of sight of the pilot who can also see other airborne traffic and manoeuvre to ensure separation. However, we are now seeing larger and higher performance RPAS and UAS operating in many different environments, at higher altitudes and beyond line of sight of the pilot operating them.

Currently in Australia there are several techniques used to ensure effective separation of crewed and uncrewed aircraft. The most common ones are segregated airspace, setting up temporary restricted or danger areas for the operation, putting in place NOTAMS to advise other airspace users of the operation, or the RPA pilots using ADS-B IN technology to assist them in locating other aircraft. However, in Australia without a special permission RPAS are not allowed to transmit ADS-B information to the aircraft around them.

The development of effective techniques to allow RPAS to 'see and avoid' other aircraft is currently ongoing and there are multiple systems that are using cameras and other sensors to assist RPAS to locate other aircraft. However, as with the human eye relying on cameras and sensors to detect other aircraft is not always a foolproof solution as with the human eye visible light cameras cannot see through cloud, heat sensors may incorrectly detect birds as threat, or a flock of birds may simply overcome the computers processing power to allow for effective avoidance. Furthermore, these techniques do not alert the pilots operating other aircraft around the RPAS about the hazard.

ADS-B technology can overcome many of these issues. If both the RPAS and the crewed aircraft are transmitting and receiving position information, they can know the type of aircraft and where it is well before it becomes a threat. Not only does this assist in collision avoidance but it reduces workload on agencies not having to segregate airspace or issue NOTAMS.

Soon the effective integration of RPAS and UAS into the airspace system around the world is going to be a necessity. 'Detect and avoid' is, by necessity, going to have to replace 'see and avoid' as the main method by which aircraft and pilots ensure self-separation in airspace where ATC does not provide a separation service. Whether this is using ADS-B or a similar technology remains to be seen, but the mid-air collision at Mangalore demonstrated the limitations of 'see and avoid' as a risk control, and the ATSB simulation of both the cockpit view and the ADS-B technology shows how 'detect and avoid' will be a key piece of effective airspace management for both crewed and uncrewed aircraft well into the future.

Footnotes

(1) En Route Supplement Australia (ERSA): a directory for Australian aerodromes that includes details of an aerodrome and details of available air traffic and ground services, navigation aids and public facilities and any special procedures.

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