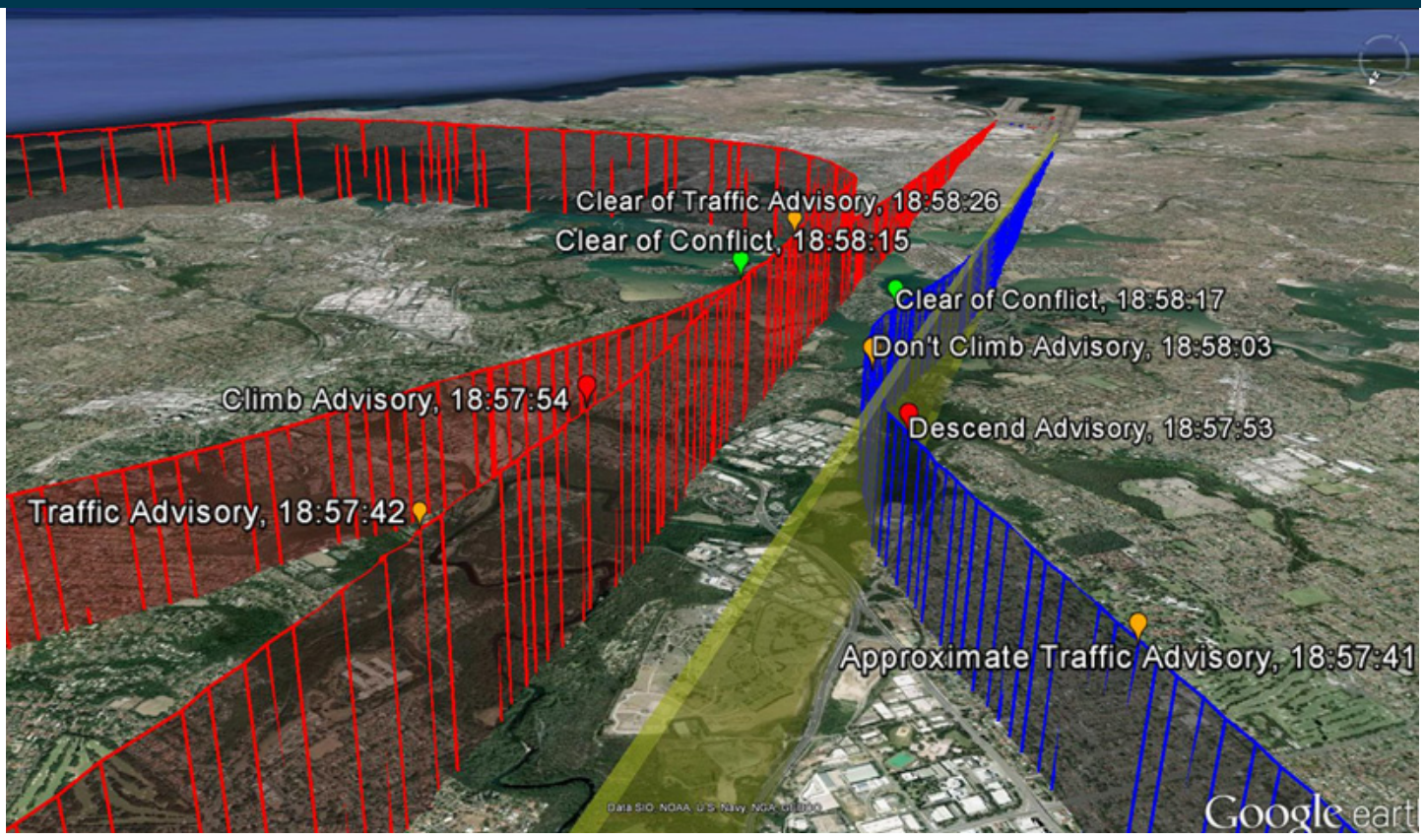
Australian Government
Australian Transport Safety Bureau

Flight path management occurrence involving Boeing 737, VH-YIR

Sydney Airport, New South Wales | 4 June 2013



Investigation

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Addendum

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Safety summary

What happened

On 4 June 2013, a Boeing 737-800 (737) aircraft, registered VH-YIR and operated by Virgin Australia (Virgin), was on a scheduled passenger service from Melbourne, Victoria to Sydney, New South Wales. During descent into Sydney, the crew was advised by air traffic control (ATC) to expect an independent visual approach (IVA) to runway 16 Right (16R).

As the aircraft approached the extended centre-line of runway 16R, the aircraft's traffic collision avoidance system (TCAS) provided a traffic alert followed by a resolution advisory (RA) in relation to an Airbus A320 aircraft on approach to parallel runway 16 Left (16L). As the crew commenced descent in response to the RA, the aircraft continued through the extended centre-line of runway 16R by about 300 m. When the TCAS alert ceased, the pilot flying captured the extended runway centre-line from the other side. The flight crew continued the approach and landed, whilst the A320 executed a go-around procedure.

As both aircraft were cleared and utilising IVA procedures, the occurrence did not constitute an ATC loss of separation assurance.

What the ATSB found

The ATSB found that the 737 passed through the centre-line as a result of the aircraft's automatic flight control system not being set to the correct flight mode for an intercept and turn onto the runway 16R localiser. This most likely occurred due to insufficient force being applied to the approach mode push-button and, as the flight crew did not perform an effective check of either the mode control panel or the flight mode annunciator to verify a mode change, they were unaware that the aircraft's flight mode was not set as intended.

The ATSB also found that the risk of an undetected mode selection error was increased as the Virgin procedures did not mandate that flight crew announce flight mode changes.

There were no technical failures of the aircraft, aircraft tracking systems or ground equipment in relation to this occurrence.

What's been done as a result

In response to this occurrence, Virgin introduced a flight policy requiring crews to verbally announce flight mode changes when operating above 500 ft.

Safety message

During an IVA, accurate interception and tracking of the runway centre-line is essential to maintain separation with aircraft using the parallel runway. This occurrence highlights the importance of pilots remaining vigilant during this type of approach, including to the consideration of and response to all RAs. The importance of crews conducting comprehensive checks of the mode control panel and flight mode annunciator to ensure that the flight mode selected is consistent with the crew's intention is also reinforced.

Contents

The occurrence

On 4 June 2013, a Boeing 737-800 aircraft (737), registered VH-YIR and operated by Virgin Australia, was on a scheduled passenger service from Melbourne, Victoria to Sydney, New South Wales. The captain was the pilot flying (PF) and the first officer (FO) was the pilot monitoring (PM).[1]

On first contact with an approach controller, flight crews are required to notify receipt of the latest automatic terminal information service[2] broadcast for their destination. At 1845 Eastern Standard Time,[3] the flight crew contacted the Sydney Approach controller for approach clearance and were cleared to descend to 8,000 ft for runway 16 Right (16R).[4] The crew were also advised to expect an independent visual approach (IVA).[5] At that time, the aircraft was 46 NM (85 km) to the south-west of Sydney.

At 1848, the flight crew of an Airbus A320 (A320), registered VH-VFL and operated by Jetstar Airways, contacted the Sydney Approach controller from a location 53 NM (98 km) to the north of Sydney. The approach controller cleared the A320 flight crew to descend to 8,000 ft for runway 16L and advised the crew to expect an IVA. At that time the 737 was 25 NM (46 km) to the south-west of Sydney on descent to a re-cleared 6,000 ft.

The Sydney Director[6] assigned the 737 flight crew a right turn heading 070° and descent to 3,000 ft at 1854:51. Shortly after at 1855:07, the Director instructed the crew to continue on their current heading and advised that there was a chance they may be taken off the approach as there was medical traffic heading north-east from Bankstown. Figure 1 illustrates the relative position and flight paths of the 737 and A320 to Bankstown Airport.

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1 Pilot Flying (PF) and Pilot Monitoring (PM) are procedurally assigned roles with specifically assigned duties at specific stages of a flight. The PF does most of the flying, except in defined circumstances; such as planning for descent, approach and landing. The PM carries out support duties and monitors the PF's actions and aircraft flight path.

2 An automated pre-recorded transmission indicating the prevailing weather conditions at the aerodrome and other relevant operational information for arriving and departing aircraft. At Sydney, this operational information would include for relevant arriving aircraft/crews to expect an independent visual approach.

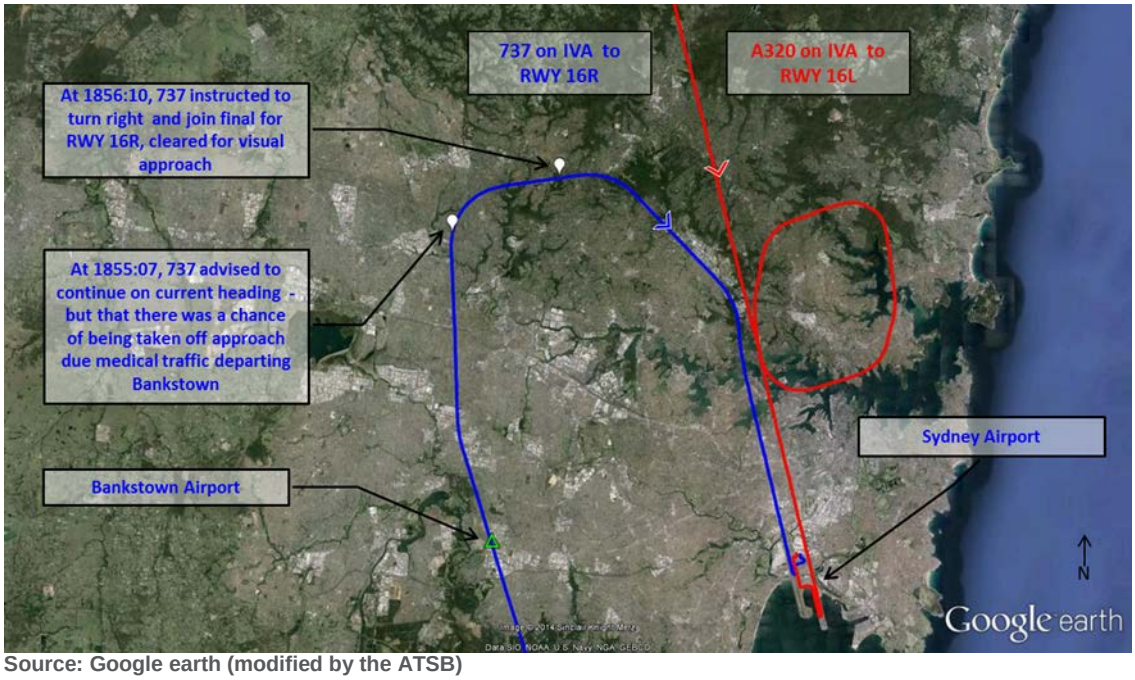
3 Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours.

4 Runways are named by a number representing the magnetic heading of the runway.

5 Independent visual approaches conducted at Sydney Airport allow simultaneous operations to parallel runways under specific conditions. One requirement of these approaches is that aircraft do not cross the extended centre-line of the assigned runway during an intercept of the final approach path.

6 The Director is an air traffic controller who is responsible for spacing and horizontal separation on final approach to the runways at Sydney airport. This is distinct from 'Sydney Tower' controllers, who provide aircraft with final clearance to land and for take-off.

Figure 1: 737 and A320 approach paths for arrival at Sydney Airport



Source: Google earth (modified by the ATSB)

At 1856:10 the Director instructed the 737 flight crew to turn right onto a heading of 125° to join final for runway 16R, and cleared the crew for a visual approach with a requirement to not descend below 2,000 ft until established on the precision approach path indicator (PAPI).[7] The 737 flight crew reported that at that stage of an approach they would normally select the approach mode, which involves the PF pressing the approach push-button on the aircraft's mode control panel. With this flight mode armed, and given the reliance on the instrument landing system (ILS)[8] at Sydney to conduct IVA approaches (see the section titled *Independent visual approaches*), the aircraft's automatic flight control system (AFCS) flies the heading selected by the crew until the aircraft captures the ILS localiser signal. Once captured, the AFCS follows the localiser course, which coincides with the runway extended centre-line in this case. The captain recalled selecting the approach mode using the push-button but stated that the action may not have been sufficiently forceful to enable the selection. The FO also recalled the captain announcing a mode change by stating 'arming approach', and considered that the approach push-button was pressed. However, recorded data indicated that the captain's action to select the push-button was not effective. Neither pilot could clearly recall verifying a change on the flight mode annunciator (FMA)[9] to confirm that the approach mode was armed.

Radar data indicated that at 1857:27, the 737 was at 3,100 ft, with a ground speed of 210 kt, on a heading of 124° and 1.7 NM (3.2 km) from the extended centre-line of runway 16R. The 737 was 1.6 NM (3.0 km) from the A320 with 700 ft vertical distance between the aircraft.

At 1857:42, the A320's traffic collision avoidance system (TCAS)[10] provided a traffic advisory (TA)[11] in relation to the proximity of the 737. The 737 crew received a TCAS TA at about the same time. The FO on the 737 recalled hearing the TA and initially thought it related to the medical

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7 A ground-based, visual approach indicating system that uses a colour discriminating system to assist pilots identify the correct glide path to the runway.

8 A standard ground aid to landing, comprising two directional radio transmitters: the localiser, which provides direction in the horizontal plane; and the glideslope, for vertical plane direction, usually at an inclination of 3°. Distance measuring equipment or marker beacons along the approach provide distance information.

9 The FMA is located at the top of each pilot's primary flight display and informs the crew of the active and armed auto-flight and auto-throttle modes.

10 Traffic collision avoidance system (TCAS) is an aircraft collision avoidance system. It monitors the airspace around an aircraft for other aircraft equipped with a corresponding active transponder and gives warning of possible collision risks.

11 When a TA is issued, pilots are instructed to initiate a visual search for the traffic causing the TA.

traffic referred to earlier by air traffic control (ATC). The FO looked at the aircraft's navigation display and noted an aircraft behind and to the left of the 737.

At 1857:53, the 737's TCAS provided a resolution advisory (RA)[12] alert to descend. The captain reported becoming aware of a flight path deviation at about the same time as the RA, and noticed that the aircraft was about to pass through the centre-line for runway 16R. The captain disconnected the autopilot at 1857:57 and manually commenced a descent to comply with the RA.

At the same time, the 737 passed through the extended centre-line for runway 16R and, at 1858:03, the RA changed from 'descend' to 'don't climb'. At 1858:12 the aircraft reached its maximum deviation (320 m) to the left of the runway 16R extended centre-line.

The A320's flight crew received a 'climb' RA at 1857:54 before advising ATC at 1858:05 of that alert. The 737 crew advised ATC at 1858:10 that they too had received an RA.

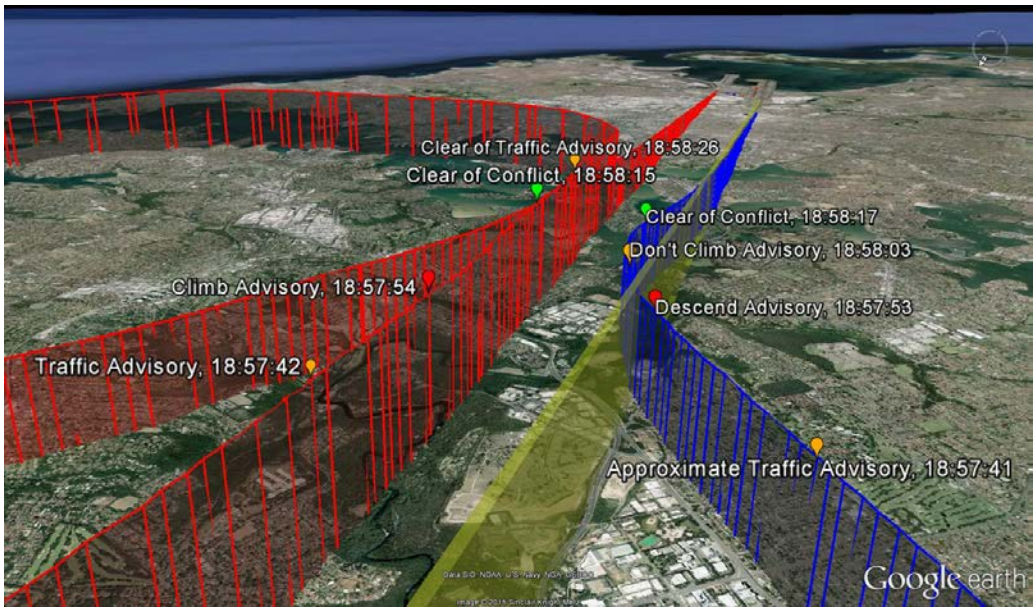
At 1858:17 the 737's TCAS provided a 'clear of conflict' annunciation, which the crew conveyed to ATC. The Director asked the 737 crew if they were able to continue the approach, and the crew replied that they could. At 1858:30, the 737 captain armed the approach mode. At 18:58:32 the AFCS captured the localiser and, at 18:59:44, the AFCS captured the glideslope before the aircraft landed at about 1900.

At 1858:26 the A320 crew advised they were clear of the conflict, and were provided instructions to re-sequence for another approach. This entailed a left turn to re-intercept the extended centre-line of runway 16L (Figure 1).

As both aircraft were cleared for and using IVA procedures, the occurrence did not constitute an ATC loss of separation assurance.[13]

The aircraft flight paths during final approach and the sequence of recorded TCAS events for the 737 and A320 are shown in Figure 2.

Figure 2: Aircraft flight paths (737 shown in blue (runway 16R) and the A320 in red (runway 16L)) and TCAS events



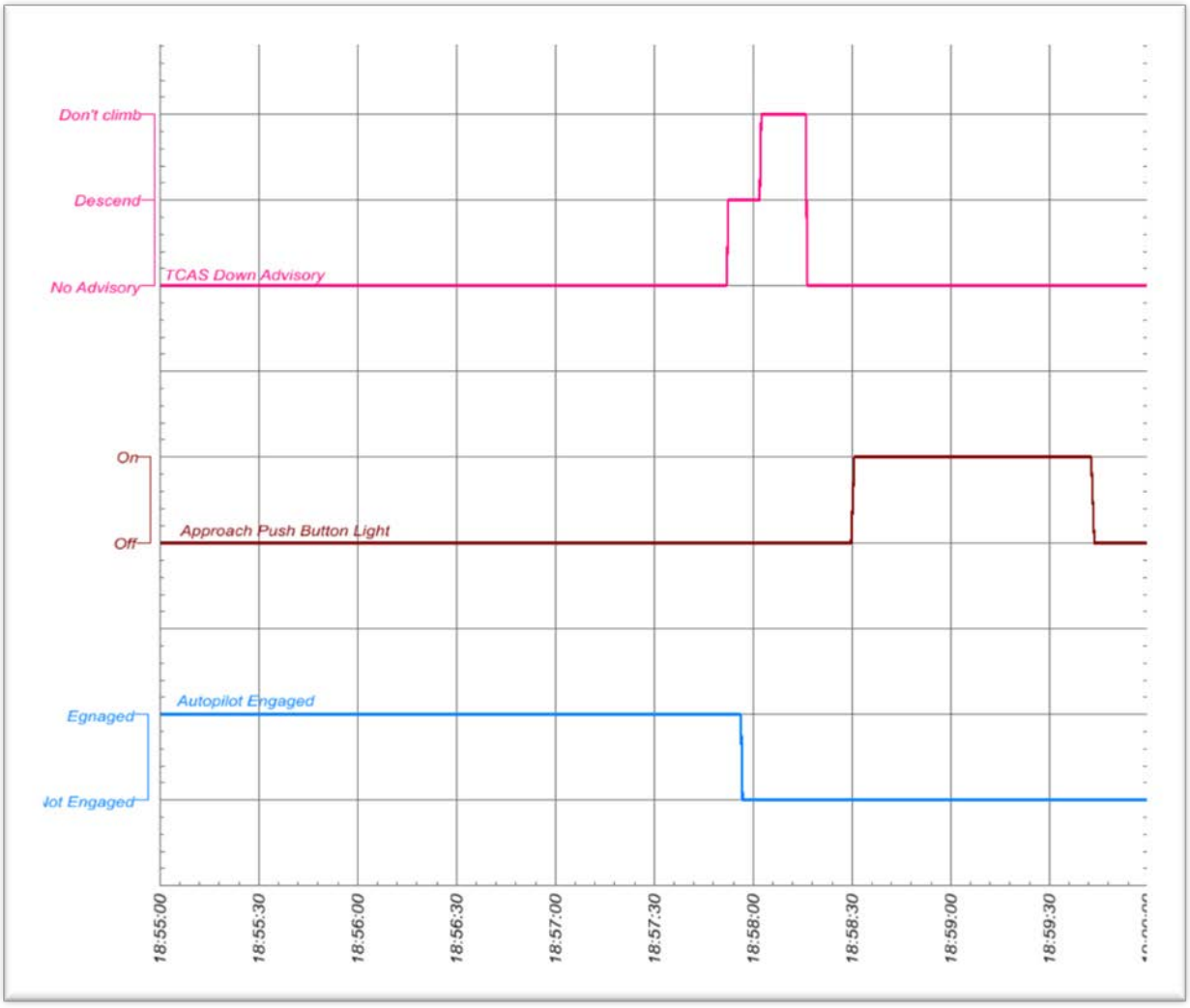
Source: Google earth (modified by the ATSB)

[12] An indication given to the flight crew recommending a manoeuvre or a manoeuvre restriction to avoid collision. RAs can be divided into two categories: corrective advisories, which advise the pilot to deviate from the current flight path (for example 'descend'); and preventive advisories, which advise the pilot to maintain or avoid certain vertical speeds (for example 'don't climb').

[13] Loss of separation assurance describes a situation where a separation standard existed but planned separation was not provided or separation was inappropriately or inadequately planned.

Flight data for selected parameters associated with approach mode selection and the TCAS advisories from the 737 are illustrated at Figure 3.

Figure 3: Recorded flight data from the 737



Source: ATSB

Context

Personnel information

Qualifications and experience

The captain held an Air Transport Pilot (Aeroplane) Licence ATP(A)L. The captain's total aviation experience was about 16,000 hours of which 7,000 hours were on the 737. They had flown the 737 with Virgin Australia (Virgin) for 11 years, with 6 years as pilot in command.

The first officer (FO) held an ATP(A)L and had previously obtained their Commercial Pilot Licence in 2004. The FO had flown with Virgin for about 5 years and had about 2 years' experience in 737 aircraft.

Crew duty

The captain and FO each commenced duty in Sydney at approximately 0755 and operated a sector from Sydney to Cairns and then from Cairns to Melbourne before the occurrence flight from Melbourne to Sydney. Total duty time[14] for each pilot was 11 hours 43 minutes and the flights were conducted within the same time zone.

Prior to the occurrence flight the captain had 3 days off duty and a 9-day break from flying.

The captain stated that they commuted from Brisbane to Sydney on the previous evening to pre-position for the first leg out of Sydney the next morning. The Captain reported experiencing a typically restful sleep the night before the occurrence flight.

The FO was returning to work from a period of simulator training in the days preceding the occurrence. They reported receiving about 7 hours of quality sleep during the night before the occurrence.

Aircraft and operational information

Mode control panel

The aircraft's automatic flight control system includes an autopilot flight director system (AFDS) and auto-throttle, which are controlled using the AFDS mode control panel (MCP) and the flight management computer (FMC). Normally, the AFDS and auto-throttle are controlled automatically by the FMC to fly an optimised lateral and vertical flight path through climb, cruise and descent.

The MCP facilitates more direct control of the aircraft flight modes and can be used to intervene between the FMC and either of the AFDS and auto-throttle. Pilots may use the MCP to make a range of flight mode selections including autopilot engagement, course and heading, target speeds and altitudes.

The mode selector switches are pushed to select desired command modes for the AFDS and auto-throttle. The switch illuminates to indicate mode selection and that the mode can be deselected by pushing the switch again. While a mode is active, deselection can be automatically inhibited and is indicated by the switch being extinguished.

When engagement of a mode would conflict with current AFDS operation, pushing the mode selector switch has no effect. All AFDS modes can be disengaged either by selecting another command mode or by disengaging the autopilot and turning the flight directors off (Figure 4).

[14] Duty time may be defined as the period from when a crew member is required to report for a duty, until the crew member is free of the duty.

Figure 4: Mode control panel with the location of the approach mode push-button highlighted in red

Source: ATSB

Once the approach mode push-button on the MCP is pressed, the system approach mode is armed. The approach mode becomes active when the localiser and glide slope signals are captured, causing the green light on the MCP approach push-button to extinguish. Once this occurs, the only means to deactivate approach mode include:

- selecting take-off/go around (TOGA) thrust
- disengaging the autopilots and switching the flight directors off
- retuning the very high frequency navigation (VHF NAV) receivers.

Illumination of the approach push-button light indicates that the armed or active mode can be deselected. It is not an accurate indicator of the status of a selected mode. As discussed in the following description, only the flight mode annunciator (FMA) provides a true indication of the mode status.

Flight mode annunciator

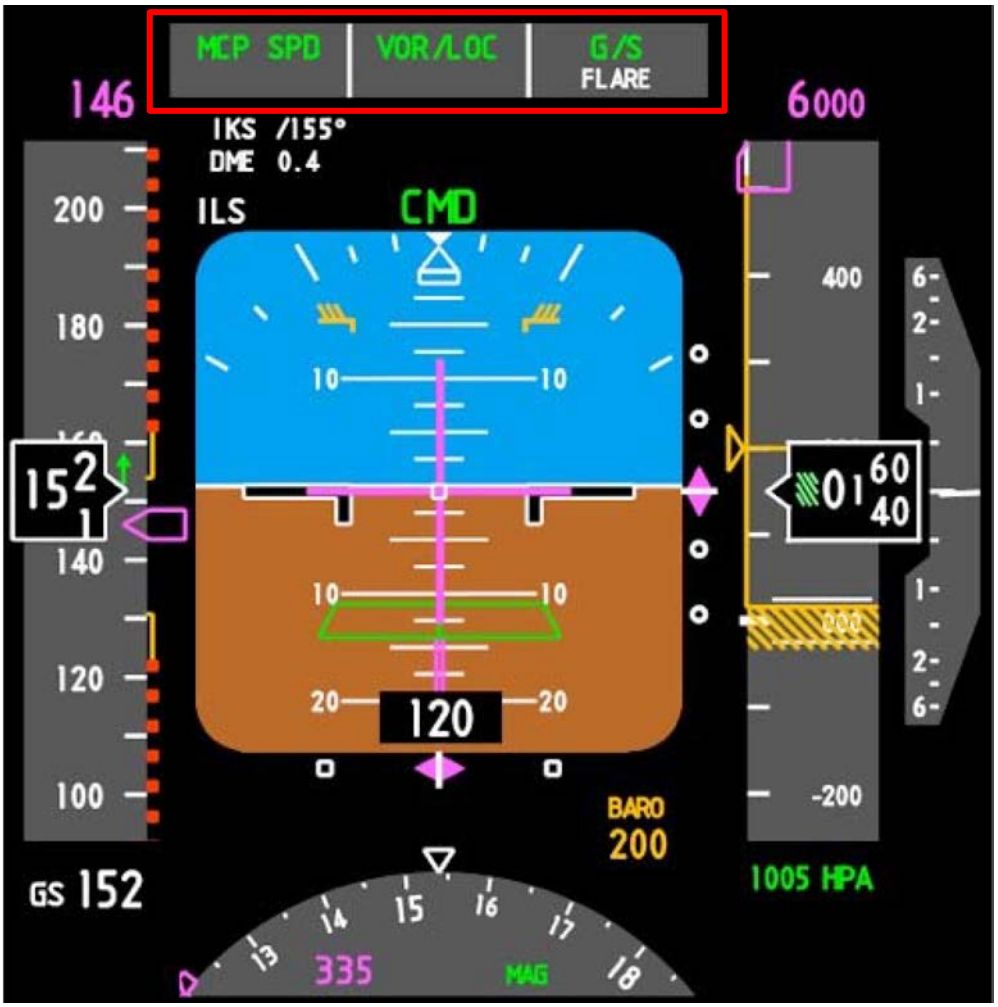
As previously stated, auto-flight system mode selections are made using the MCP. They are displayed from left to right on the FMA at the top of each pilots primary flight display (PFD) and include:

- auto-throttle
- roll (or lateral) mode
- pitch (or vertical) mode.

Engaged flight modes are displayed on the top line of the FMA in green letters and are the primary indication to the pilot that an AFDS mode is active. Armed modes are displayed in smaller, white letters beneath the engaged modes. A highlighting rectangle appears around the relevant mode annunciation for a period of 10 seconds following mode engagement. Confirmation of the status of the auto-flight system modes is made by reference to the FMA.

Figure 5 is an example of a B737 PFD for an aircraft on approach to Sydney runway 16R. The representation shows the aircraft close to touchdown with both Localiser and Approach correctly captured by dual autopilots.

Figure 5: B737 PFD with the FMA highlighted in red. The top line of the FMA shows in green text that Mode Control Panel Speed is engaged, VOR or Localiser Tracking is engaged, and Glideslope is engaged and captured. The second, lower line shows in white that Flare is armed



Source: Aerosoft Australia (modified by the ATSB)

Flight mode monitoring

The Virgin Operations Manual provided guidance regarding crew monitoring of indications, limitations and on systematic cooperation and exchange of information between flight crew. The manual also included a requirement to check FMA annunciations that may indicate downgraded capability, and for flight crew to monitor the FMA during low visibility approach and auto-land operations. However, the document did not mandate that flight crews verbally announce FMA changes.

Aircraft and ground-based systems

Under certain conditions, including as a result of ground-based technical factors, the aircraft's automation may allow the aircraft to fly through the localiser briefly, before intercepting the localiser from the other side. However, the known onboard or ground-based technical factors with the potential to cause these brief incursions did not contribute to this occurrence.

Independent visual approaches

Sydney Airport operates two parallel runways (16L/34R and 16R/34L) that are set 1,037 m apart (Figure 6). Use of the independent visual approach (IVA) procedure, which is only possible in

visual meteorological conditions,[15] allows two aircraft to be established on final approach to the parallel runways at the same time.

IVA procedures were introduced with the commissioning of runway 16L/34R in 1994. At the time of writing, Sydney Airport was the only location in Australia with parallel runways and where IVAs were in operation. All runways at Sydney Airport are instrument landing system (ILS) equipped.

Figure 6: Sydney Airport runway configuration

Source: Airservices Australia (modified by the ATSB)

Procedures

At the time of the occurrence, Airservices Australia (Airservices) published the requirements and procedures for IVAs in the Australian Aeronautical Information Publication (AIP). The AIP stated that IVAs could be conducted to parallel runways with centre-lines separated by at least 760m, provided that aircraft were making straight-in approaches that commenced at the ILS outer marker or 4 NM (7.4 km) from the runway threshold, and air traffic control (ATC) maintained a minimum 1,000 ft vertical or 3 NM (5.6 km) radar separation between the affected aircraft. These pre-conditions were stipulated until a number of additional conditions were met and an aircraft was cleared for an IVA. When an aircraft was vectored by ATC to intercept the final course, the final vector had to permit the aircraft to intercept that course at an angle not greater than 30°.

The AIP also contained a section on pilot responsibilities during IVAs. These included flying accurate headings, ensuring that the runway centre-line was not crossed during intercept, accurately tracking the runway centre-line, maintaining a visual lookout for aircraft approaching the parallel runway and advising ATC immediately when avoiding action was initiated or contact with the runway was lost.

During an IVA, accurate tracking of the runway centre-line is essential. This can be achieved either electronically (localiser, RNAV[16] or ground-based augmentation system (GBAS) landing system[17]) or visually.

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15 Conditions in which pilots have sufficient visibility to fly the aircraft maintaining visual separation from terrain and other aircraft.

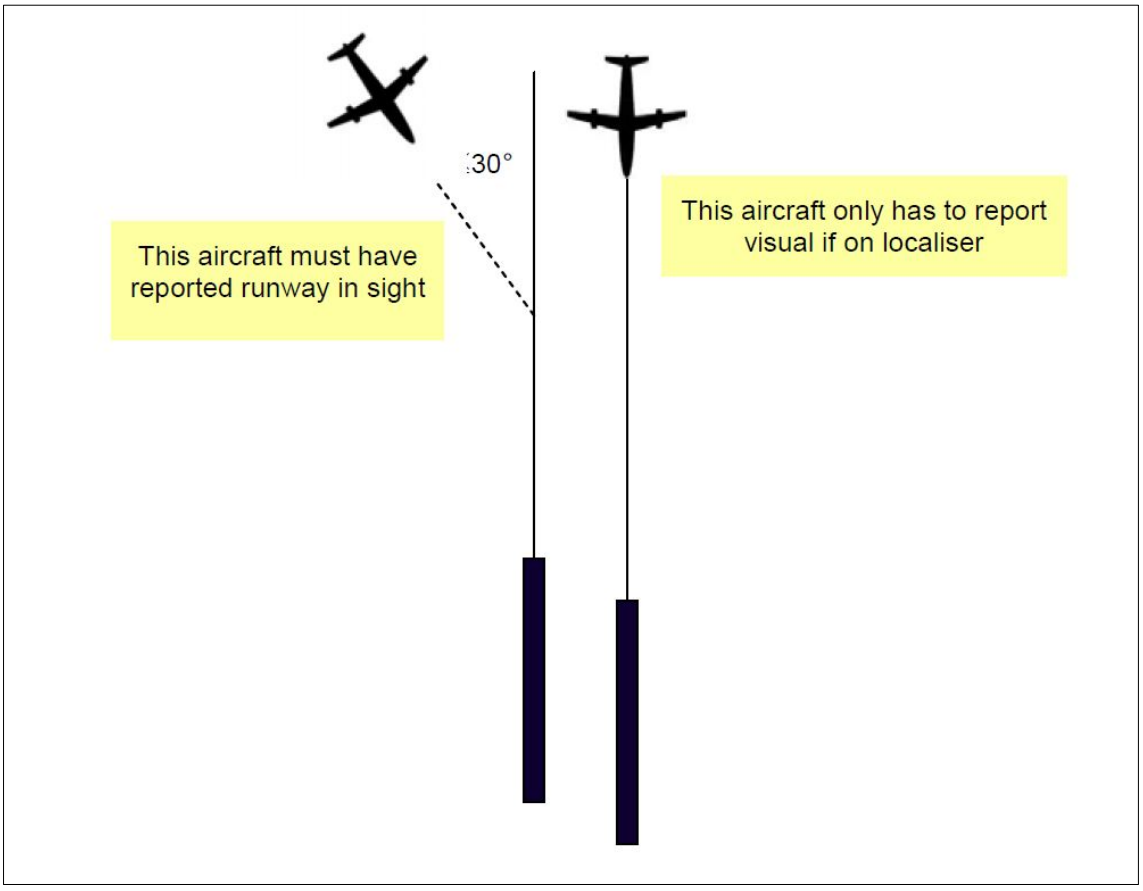
16 A method of navigation that permits aircraft operation on any desired course within the coverage of station-referenced navigation signals or within the limits of a self-contained system capability, or a combination of these.

17 A system for approach and landing operations using the GBAS augmentation system, in which the user receives information directly from a ground-based transmitter.

The difference between reporting 'visual'[18] and reporting the runway in sight is significant. A visual call by the flight crew to ATC is all that is required if established on the centre-line using electronic indications. In contrast, a specific runway in sight call is required from flight crews if they are not electronically established on centre-line (Figure 7).

Any aircraft being processed for an IVA needs to inform the Sydney ATC Director[19] when they have the runway in sight as soon as possible.

Figure 7: Runway centre-line tracking requirements



Source: Airservices Australia

A local ATC restriction was in place that did not allow foreign-based airlines (excluding New Zealand-based operators) to participate in IVAs until their aircraft was established on the runway centre-line. In addition, Qantas Airways Limited Boeing 747 aircraft were treated by ATC as a foreign international operator, due to a limitation imposed by the airline.

At Sydney Airport, the ILS critical areas[20] were not protected during IVAs. Airservices reported that aircraft operating on IVAs to runways 16L and 16R were spaced 4 NM (7.4 km) apart in trail for each runway in order to optimise the efficiency of landing rate. If the ILS critical areas were to be protected, this spacing would need to be increased to 7 NM (13 km). Together with the requirement for ground traffic to be positioned outside the ILS critical areas, leading to congestion and towing and taxiing restrictions in the remaining aircraft ground movement areas, this would result in a 39 per cent reduction in the arrival rate into Sydney per hour.

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18 By reporting 'visual' the pilot indicates their acceptance of responsibility to see and avoid obstacles during flight below the minimum vector altitude or minimum sector altitude/lowest safe altitude.

19 In Sydney, the Director(s) are the only ATC persons permitted to apply IVAs.

20 To maintain ILS signal integrity, the critical areas needed to remain clear of vehicles, aircraft and equipment.

Design and implementation

The design and implementation of IVAs at Sydney was a collaborative undertaking involving industry, the Civil Aviation Safety Authority (CASA) and Airservices.

Due to the different runway lengths and airport layout in Sydney, extensive analysis was conducted by Airservices on the operation of a parallel runway (16L/34R) prior to its construction and commissioning in 1994. A design group was formed to investigate different methods of achieving an efficient mixed-mode operation, where both runways are used for arrivals and departures. The group focused on airports with a distance between their parallel runways similar to that of Sydney.

Minneapolis St Paul and Raleigh Durham Airports, which are both located in the United States (US) and operated under Federal Aviation Administration (FAA) regulations, were selected as possible models given the distance between their parallel runways was similar to Sydney. As those airports had accumulated years of experience with mixed-mode parallel runway operations, it was determined the most efficient approach would be to adopt a similar mixed-mode operation at Sydney Airport.

Conservative restrictions were applied to the baseline FAA model to develop the IVA procedures for application at Sydney Airport. These restrictions reflected the local conditions at Sydney Airport and the then inexperience in high-capacity parallel runway operations in Australia.

Implementation of IVAs at Sydney was managed by Airservices. With support from industry and CASA, this included an information/education program involving industry meetings and presentations, the development of a training video outlining pilot and ATC responsibilities and the production of operational documentation.

Reviews of IVA operations at Sydney Airport prior to the occurrence

Civil Aviation Safety Authority

Civil Aviation Safety Regulation 1998 (CASR) Part 172 *Manual of Standards - Air Traffic Services* specifies the regulatory framework for the approval of air traffic service providers in Australia, and includes standards for air traffic facilities, safety management and the provision of air traffic services. In January 2013, CASA published the results of a review of its CASR Part 172 approval of Airservices. The review sought to identify areas for improvement of Airservices safety and service performance and to determine if conditions needed to be applied to the Airservices approval.

CASA's review determined that there was a high instance of traffic alert and collision avoidance system (TCAS) alerts at Sydney involving IVAs, and that the IVA operation was implicated in TCAS incident reports more frequently than any other event. These included traffic advisory (TA) and resolution advisory (RA) occurrences. In addition, CASA noted a number of changes in operating dynamics since the introduction of IVA procedures, such as aircraft utilising the TCAS RA mode instead of the original TCAS TA mode once used for arrivals into Sydney.

CASA also found that there were frequent occasions during the conduct of IVAs where controllers issued visual approach clearances from the downwind or base legs that resulted in aircraft intercepting adjacent, parallel final approach paths. Aircraft would then fly either 'side-by-side' or one overtake the other during final approach. It was also noted that ATC standards did not require controllers to provide positive separation between aircraft on adjacent final approaches, nor was ATC required to provide traffic information to flight crews of aircraft vectored into close proximity.

One of the recommendations from the CASA review was that, in respect of IVA operations at Sydney Airport:

> Airservices should review Independent Visual Approach (IVA) procedures at Sydney in order to determine if sufficient risk mitigators are in place to ensure the continued safe operation of aircraft.

Airservices Australia

Airservices conducted a review of parallel runway operations at Sydney Airport in 2003. The review included an evaluation of the IVA procedures at Sydney and recommended a number of improvements.

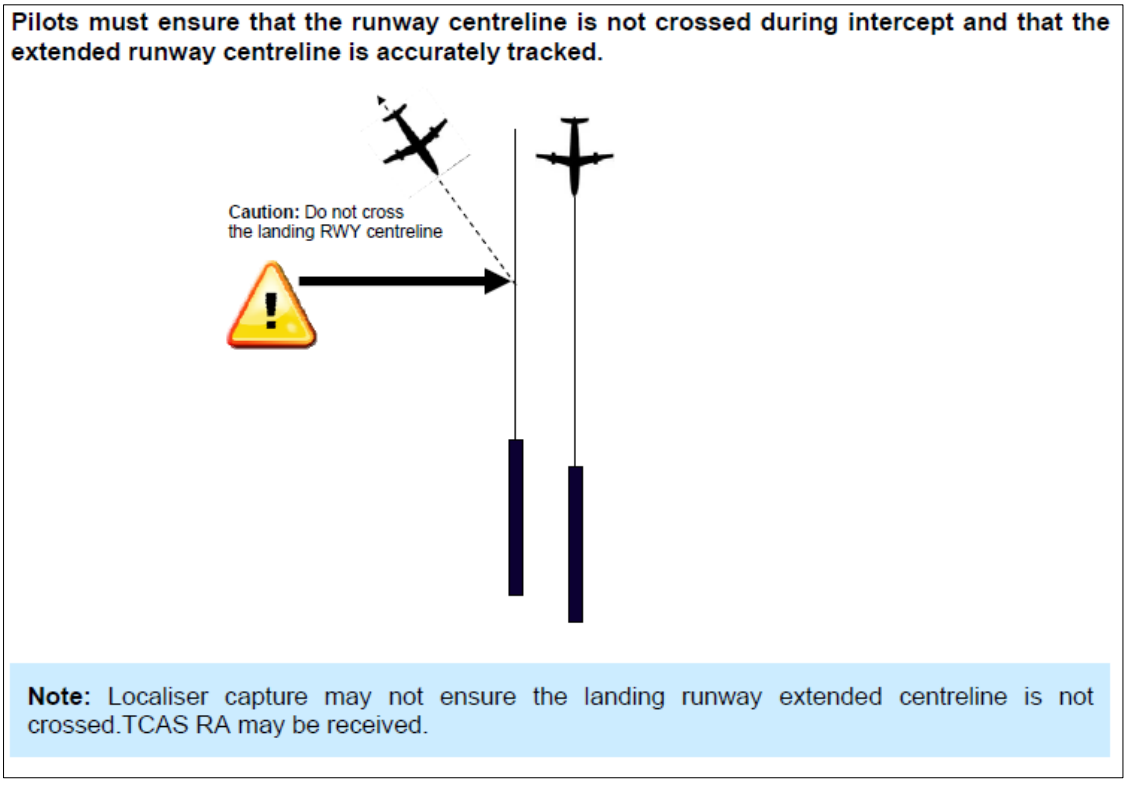
Subsequently, Airservices became aware of a potential recommendation from CASA's CASR Part 172 review in respect of IVA procedures at Sydney Airport. Airservices advised CASA that they would review the procedures in conjunction with industry and implement any agreed actions.

On 14 November 2012 Airservices revised the wording on the Sydney Automatic Terminal Information Service (ATIS)[21] in respect of IVA approaches to advise pilots to 'not pass through the assigned runway centre-line'. This revision of the Sydney ATIS was in place at the time of the occurrence on 4 June 2013.

On 20 November 2012, following a discussion with airlines, Airservices published a safety bulletin on IVAs[22] noting that their reporting system had identified the inconsistent application by some pilots of their responsibilities during IVAs. The following five pilot responsibilities were reiterated in the safety bulletin:

- Pilots ensuring that the runway centreline is not crossed during intercept (Figure 8)
- Pilots maintaining a visual lookout for aircraft approaching the adjacent parallel runway centreline
- TCAS RAs during IVAs
- Importance of "Visual" reports and the specific requirements for "specific Runway *XX Right or left* in sight"
- Pilots understanding of radio failure procedure as described in ERSA (En Route Supplement Australia)

Figure 8: Extract from Airservices Safety Bulletin – Independent Visual Approaches



Source: Airservices Australia

[21] An automated pre-recorded transmission indicating the prevailing weather conditions at the aerodrome and other relevant operational information for arriving and departing aircraft.

[22] Available from www.airservicesaustralia.com.

In addition to the safety bulletin, Airservices reported that they planned to review the IVA procedures, with airline input, in the first quarter of 2013.

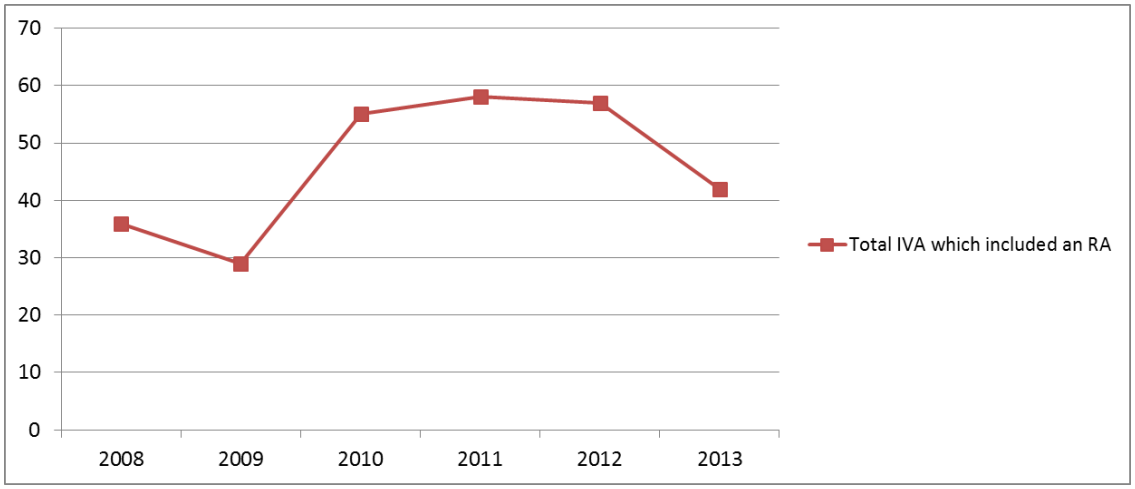
The Airservices review of IVA procedures was attended by CASA and airline and Airservices representatives. It identified a number of potential risk mitigation factors and considered the release of an order by the US FAA for ATC to review approach speeds to reduce potential overshoot situations during parallel runway operations.

On 24 November 2013, standard circuit speeds for application by Sydney ATC during IVA procedures were introduced. On 12 December 2013, a change was introduced to the phraseology used by ATC to clear an aircraft for an IVA to increase pilot awareness of the IVA procedure, given pilot responsibilities 'change slightly between a visual approach and a visual approach as part of the IVA procedure'. This required controllers to include the word 'independent' when clearing an aircraft for a visual approach during IVA procedures.

Related occurrences

A review of the ATSB and Airservices occurrence databases was undertaken to examine the number of TCAS RA occurrences during IVA operations at Sydney Airport in the period 2008-2013 (Figure 9). Based on the available information, in that period there were 277 reported RAs during IVA procedures.

Figure 9: TCAS RA occurrences during IVA operations at Sydney airport (2008–2013)



Source: ATSB

Airservices advised that over the period 2008–2013, there were about 154,000 approaches per year at Sydney Airport, and that about 60 to 85 per cent involved IVAs. Given this broad range, it was not possible to determine whether there were any trends in the rate of RA occurrences (per approach) in recent years. The ATSB was unable to compare this alert rate against the US airports using similar procedures because there were more limited requirements for reporting TCAS RA occurrences in the US.

A review of the ATSB database indicated that about 30 per cent of all reported TCAS RA occurrences in Australia, or involving Australian aircraft overseas, occurred at Sydney Airport. Data provided by Airservices indicated that about 62 per cent of all RAs in the Sydney terminal area occurred during IVA procedures. The other 38 per cent included other approaches, departures and overflying aircraft.

In certain situations, two aircraft can be flown on IVAs at Sydney in a manner consistent with the required procedures, yet both aircraft's TCAS can generate an RA. For example, of the 277 reported RA occurrences during IVAs at Sydney during 2008–2013, 30 involved one of the aircraft passing through the extended centre-line. For many of the other occurrences there was insufficient information to determine whether a deviation occurred.

The extent to which centre-line deviations occurred during IVAs when no RA was reported could not be reliably determined as there were no specific reporting requirements for such events.

Safety analysis

Introduction

While conducting an independent visual approach (IVA) to runway 16R at Sydney Airport, the flight crew of a Boeing 737 (737), registered VH-YIR and operated by Virgin Australia (Virgin), passed through the runway centre-line as an Airbus A320 aircraft, registered VH-VFL, was conducting an IVA to parallel runway 16L. Both flight crews received a traffic advisory (TA) followed by a resolution advisory (RA) through their aircraft's traffic collision avoidance systems (TCAS) and acted in accordance with their respective RA instructions. At that time, the 737 captain realised they were passing through the extended runway 16R centre-line and disengaged the autopilot before manually flying the aircraft back towards the centre-line. The flight crew then armed the approach mode, which captured the localiser course. The flight crew of the A320 performed a go-around, and both aircraft landed safely. Although the occurrence was far from developing into a collision, and both aircraft were in visual meteorological conditions, this analysis examines the crew actions and IVA procedures at Sydney Airport and their influence on the development of the occurrence.

Arming the approach and mode awareness

The mode control panel (MCP) is the interface between the flight crew and the aircraft's automatic flight control system (AFCS). Pressing the approach mode push-button on the MCP illuminates the integral push-button light, indicating that the crew have 'issued an instruction' to the AFCS. The flight mode annunciator (FMA) then displays a message as a means of feedback from the AFCS to the crew confirming either that a mode is armed or active. Checking both the MCP and the FMA is therefore critical to the flight crew's continued awareness of the aircraft's mode status.

Checking the FMA

Although it seems logical that a pilot would check the FMA, research has shown that they do not always do so, even when flight crews are required to call out auto-flight mode changes (Björklund and others 2006). Other research has suggested that 32 per cent of pilots do not observe the FMA within the first 20 seconds of a manually-selected mode change (Mumaw and others 2001).

Björklund and others (2006) state:

> Two out of five mode transitions on the FMA were never "seen" by the flight crews. In contrast to instrument monitoring in non-glass-cockpit aircraft, monitoring for mode transitions is likely to be based more on a pilot's mental model of the automation that drives expectations of where and when to look. Such models are often incomplete and buggy (e.g., Sarter, 1995). Therefore, it may not be surprising that many mode transitions in this study are neither visually nor verbally verified by flight crews, and that the FMA triggered only 4% of call-outs in this study, of which one out of four was not the official call-out. The FMA did not get consulted for 40% of all mode transitions.

Goteman and Dekker (2006) also found that FMA call-outs were shed when pilots were under a higher task load. It was also found that compliance with the required call-outs was higher when the operator only required a selected set of mode changes to be called.

Mode awareness

In an effort to increase pilots' mode awareness, aircraft manufacturers have recommended that pilots call out mode (or FMA) changes. Many operators have incorporated this into their operating procedures.

Ineffective auto-flight system mode awareness has been identified as a contributing factor in many occurrences since the introduction of complex auto-flight systems (Federal Aviation Administration 1996). Attempts to address the problem have only been partially successful, as a 2013 report into

operations of flight path management systems (Flight Deck Automation Working Group 2013) stated:[23]

> The 1996 FAA report[24] identified insufficient autoflight mode awareness as an important vulnerability area. Since that [the 1996] report was published, some changes to flight deck equipment design have been made in new aircraft to address this vulnerability area (e.g., only showing selected target values or modes on the PFD [Primary Flight Display], to foster the pilots reviewing the information on the mode annunciator display rather than on the mode selection panel).
>
> In addition, the issue has been addressed in training through increased emphasis on mode awareness and in some operators' flight crew procedures by having the pilots call out all mode changes. However, other operators find this use of callouts to be too burdensome and a potential distraction.
>
> These mitigations are only partially successful. The data analysis reveals that autoflight mode selection, awareness and understanding continue to be common vulnerabilities.

In this occurrence, it was found that, contrary to their intentions, the 737 flight crew did not arm the approach mode, probably as a result of applying insufficient force to the mode push-button. Subsequently, the crew's check/confirmation, if any, of the mode change using either the MCP or FMA was ineffective. This meant the crew's belief of their selection of the approach flight mode led to an incorrect expectation that the aircraft would automatically capture the localiser.

Virgin did not mandate that its crew announce mode changes at the time of the occurrence. Despite the absence of this procedural requirement, the 737 captain made a verbal call announcing their selection of the approach mode. However, the flight crew did not effectively verify via the FMA display that approach mode was armed.

Flight path monitoring

As the 737 turned on final to intercept the extended runway 16R centre-line, the flight crew expected that the aircraft's autopilot system would capture the localiser via the automated approach mode. As the flight continued, the flight crew did not anticipate that the aircraft was about to fly through the centre-line.

About 16 seconds prior to passing through the centre-line, the TA provided by the aircraft's TCAS was the first indication of a potential problem with the aircraft's flight path. The first officer (FO), who was the pilot monitoring, reported hearing the TCAS TA and that they considered it may have been due to the previously-advised medical traffic departing Bankstown. Although the captain, who was the pilot flying, described the medical traffic as a minor distraction, the FO remained concerned about its location. This distraction probably reduced the crew's ability to fully appreciate the location of their own aircraft and anticipate its future position relative to the runway centre-line.

Flight crew response to the TCAS advisories

Automated conflict detection and alerting systems such as TCAS form a fundamental layer of defence against collision through their traffic and resolution advisory functionality. In this occurrence, the TCAS system performed as expected and provided the necessary stimulus for the crew of the 737 to disengage the autopilot and manually fly the aircraft back toward the runway16R centre-line.

The FO recalled the TCAS TA and, although immediately thinking it must have been a consequence of the medical traffic, decided to refer to the TCAS display. This display indicated the traffic as an A320 to the left-rear of the 737. The captain was previously aware of the A320 and acknowledged the value of TCAS as a situation awareness tool.

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[23] Performance-based operations Aviation Rulemaking Committee/Commercial Aviation Safety Team Flight Deck Automation Working Group, 2013.

[24] Federal Aviation Administration 1996, *The Interfaces Between Flight crews and Modern Flight Deck Systems.*

Twelve seconds passed between the TCAS TA and RA, with recorded data verifying that the 737 flight crew responded by disengaging the autopilot within 4 seconds of the RA. Recorded data also showed that, during the initial 12-second period, the captain described observing a number of unexpected external visual cues, until such time as the aircraft continued through the runway 16R centre-line. There was no obvious action taken to rectify the aircraft's flight path during the period between the TA and the RA.

Although Virgin's Operations Manual stated that all TCAS warnings were to be treated as genuine and action taken in response, there have been anecdotal reports among a number of operators of TCAS TAs being considered of nuisance value during IVAs at Sydney. This may be due to the technical limitations of TCAS, leading to a 'cry wolf' effect (Wickens and others 2009), or reduced trust and use of the system during IVAs due to false alarms associated with the inherent parallel runway proximity to other aircraft.

There was no irrefutable evidence to suggest that pilots ignore TCAS TAs or RAs during IVA procedures at Sydney.

Fatigue

Thomas and Ferguson (2010) examined the effects of different amounts of sleep on the performance of Australian airline flight crews. The study found that the average amount of sleep in the previous 24 hours for captains was 7.0 hours and 7.1 hours for FOs. The occurrence of crew errors was higher, and threat management poorer, during flights when the crew included a captain with less than 6 hours sleep or a FO with less than 5 hours sleep in the previous 24 hours.

It is generally agreed that most people need at least 7 to 8 hours of sleep each day to achieve maximum levels of alertness and performance. Both pilots reported receiving an adequate amount of rest which was conducive to the vigilance, reaction times and cognitive requirements of the flight.

Although both of the crew reported obtaining an adequate amount of quality sleep the previous night, the occurrence took place during the last leg of an 11 hour 43 minute duty period. Although consistent with the captain's report of experiencing some degree of tiredness during the final leg, it could not be concluded that this equated to a level of fatigue likely to affect the crew's performance of the task; in particular, their ability to make and verify flight mode selections.

Independent visual approaches

As the crew approached the extended centre-line of runway 16R, the captain was aware of an A320 on approach to runway 16L. The captain reported that it was only from using the TCAS that they gained an accurate understanding of the A320's position and altitude. This may be due, in part, because ATC did not, and was not required to provide, traffic information to aircraft using adjacent runways and abeam each other during independent visual approach procedures at Sydney. Traffic information regarding the A320 may have assisted the crew of the 737 form an accurate traffic picture at a critical point during the final approach phase.

Relative to other approaches and flight operations, there is a relatively high rate of RAs during IVA procedures at Sydney. This reinforces the need for compliance with the IVA procedures into Sydney and for flight crew to assure themselves that the correct flight mode has been selected. Confirmation of the correct flight mode will allow crews to focus on additional aspects of the approach, including surrounding traffic and flight path monitoring during the critical stages of flight.

Findings

From the evidence available, the following findings are made with respect to the flight path management occurrence involving Boeing 737, registered VH-YIR and operated by Virgin Australia, which occurred at Sydney Airport, New South Wales on 9 June 2013. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance. A safety issue is an event or condition that increases safety risk and (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.

Contributing factors

- The flight crew applied insufficient force to the approach mode push-button on the mode control panel to arm the mode, which was not identified during their subsequent check of the flight mode annunciator.
- Due to their expectation that the aircraft approach mode was armed, and a subsequent degradation in monitoring the aircraft's systems, the flight crew did not anticipate that the aircraft's automated systems would not capture the runway 16R localiser and did not immediately detect the flight path deviation.
- The flight crew did not recognise that the traffic advisory alert provided by the aircraft's traffic collision avoidance system 12 seconds prior to the aircraft passing through the runway centre-line was a potential indication of a problem with the aircraft's flight path.

Other factors that increased risk

- **The Virgin Australia procedures did not require its flight crew to, whenever practicable, announce flight mode changes. [Safety issue]**
- **Air traffic control did not, and was not required to provide traffic information to aircraft using adjacent runways and abeam each other during independent visual approach procedures at Sydney. [Safety issue]**

Other findings

- Relative to other approaches or flight operations, there is a relatively high rate of traffic collision avoidance system resolution advisory alerts during independent visual approaches at Sydney Airport.

Safety issues and actions

The safety issues identified during this investigation are listed in the Findings and Safety issues and actions sections of this report. The Australian Transport Safety Bureau (ATSB) expects that all safety issues identified by the investigation should be addressed by the relevant organisation(s). In addressing those issues, the ATSB prefers to encourage relevant organisation(s) to proactively initiate safety action, rather than to issue formal safety recommendations or safety advisory notices.

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.

Annunciation of mode changes

Number:	AO-2013-095-SI-01
Issue owner:	Virgin Australia
Operation affected:	Aviation: Air Transport
Who it affects:	Virgin Australia flight crews

Safety issue description:

The Virgin Australia procedures did not require its flight crews to, whenever practicable, announce flight mode changes.

Proactive safety action taken by Virgin Australia

Action number: AO-2013-095-NSA-022

Virgin Australia reported that, on 7 June 2013, the following changes were made to its flight policies:

> Flight Mode Annunciator Changes. Virgin Australia policy is that Flight Mode Annunciator [FMA] changes should be announced by the PF [pilot flying].
>
> Due to high workload, FMA changes below 500AFE [above field elevation] only need to be made if required by specific aircraft operations manual.
>
> The PM [pilot monitoring] should announce the change if missed by the PF.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that the change in policy requiring the announcement of flight mode changes has adequately addressed the safety issue.

Provision of traffic information

Number:	AO-2013-095-SI-02
Issue owner:	Airservices Australia
Operation affected:	Aviation: Airspace Management
Who it affects:	All Sydney Terminal Control Unit Director controllers

Safety issue description:

Air traffic control did not, and was not required to provide traffic information to aircraft using adjacent runways and abeam each other during independent visual approach procedures at Sydney.

Proactive safety action taken by Airservices Australia

Action number: AO-2013-095-NSA-023

On 11 December 2013, Airservices Australia (Airservices) implemented a requirement for Sydney air traffic control to provide traffic advice whenever aircraft would operate within 1 NM (1.85 km) of traffic on the adjacent final approach during independent visual approach (IVA) procedures. The instruction stated that:

> To enhance pilot situational awareness, the phraseology will include the aircraft type and whether the aircraft is ahead, behind or adjacent.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The ATSB is satisfied that the safety action implemented by Airservices has adequately addressed the safety issue.

Additional safety action

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. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Airservices Australia

On 11 March 2014, Airservices published an updated page on their website for IVAs at Sydney Airport. The page outlined the procedures, requirements and pilot responsibilities for application during IVAs and included a training video on IVAs at Sydney Airport and a number of sources of IVA information.

General details

Occurrence details

Date and time:	4 June 2013 – about 1858 EST	
Occurrence category:	Incident	
Primary occurrence type:	Airspace - Aircraft separation - airborne collision alert system warning	
Location:	Sydney Airport, New South Wales	
	Latitude: 33° 56.77' S	Longitude: 151° 10.63' E

Aircraft details

Manufacturer and model:	Boeing 737-8 FE	
Registration:	VH-YIR	
Operator:	Virgin Australia	
Serial number:	39925	
Type of operation:	Air Transport High Capacity	
Injuries:	Crew – Nil	Passengers – Nil
Damage:	Nil	

Manufacturer and model:	Airbus A320-232	
Registration:	VH-VFL	
Operator:	Jetstar Airways	
Serial number:	5489	
Type of operation:	Air Transport High Capacity	
Injuries:	Crew – Nil	Passengers – Nil
Damage:	Nil	

Sources and submissions

Sources of information

The sources of information during the investigation included:

- Virgin Australia (Virgin) and Jetstar Airways
- the 737 flight crew
- Airservices Australia (Airservices)
- the Manual of Air Traffic Services

References

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Goteman, O & Dekker, S 2006, Flight crew callouts and aircraft automation modes: An observational study of task shedding, *International Journal of Applied Aviation Studies*, vol. 6, pp. 235–248.

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Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act 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 flight crew, Virgin, Airservices, Jetstar and the Civil Aviation Safety Authority.

Submissions were received from Virgin and Airservices. The submissions were reviewed and where considered appropriate, the text of the report was amended accordingly.

Australian Transport Safety Bureau

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; fostering safety awareness, knowledge and action.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the *Transport Safety Investigation Act 2003* and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to identify and reduce safety-related risk. ATSB investigations determine and communicate the factors related to the transport safety matter being investigated.

It is not a function of the ATSB to apportion blame or determine liability. At the same time, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

Developing safety action

Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to initiate proactive safety action that addresses safety issues. Nevertheless, the ATSB may use its power to make a formal safety recommendation either during or at the end of an investigation, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation.

When safety recommendations are issued, they focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on a preferred method of corrective action. As with equivalent overseas organisations, the ATSB has no power to enforce the implementation of its recommendations. It is a matter for the body to which an ATSB recommendation is directed to assess the costs and benefits of any particular means of addressing a safety issue.

When the ATSB issues a safety recommendation to a person, organisation or agency, they must provide a written response within 90 days. That response must indicate whether they accept the recommendation, any reasons for not accepting part or all of the recommendation, and details of any proposed safety action to give effect to the recommendation.

The ATSB can also issue safety advisory notices suggesting that an organisation or an industry sector consider a safety issue and take action where it believes it appropriate. There is no requirement for a formal response to an advisory notice, although the ATSB will publish any response it receives.

Australian Transport Safety Bureau

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Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation

Flight path management occurrence involving Boeing 737, VH-YIR Sydney Airport, New South Wales, 4 June 2013

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