



Australian Government
Australian Transport Safety Bureau

Erratic airspeed indications, Boeing 787-8, VH-VKE

450 km north of Darwin, Northern Territory | 21 December 2015



Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation
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Addendum

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Safety summary

What happened

On 21 December 2015, a Boeing 787-8 aircraft, registered VH-VKE, departed Melbourne, Australia on a scheduled passenger transport service to Singapore. Approximately 4 hours into the flight, just north of Australia, the airspeed indications became erratic. As a result, the autopilot disconnected and the Primary Flight Control reverted to a mode with fewer automated functions and protections. After approximately 17 seconds the airspeed values returned to normal.

Due to the latching nature of the Primary Flight Control mode reversion, the aircraft had to be manually flown for the remainder of the flight and because of this, the crew diverted the aircraft and made an uneventful landing in Darwin, Australia.

What the ATSB found

The ATSB found that the aircraft had entered an area of weather with high ice water content, which caused the pitot-static systems to become affected by ice. The flight control logic detected a resulting drop in airspeed, sufficient to revert to secondary mode.

What has been done as a result

Boeing revised the flight control software to reduce the chances of reverting to secondary mode in a short duration, erratic airspeed event.

In response to a previous, similar event on another B787-8, the FAA published an airworthiness directive warning flight crew not to make large abrupt magnitude flight control inputs in response to unrealistic drops in airspeed.

Boeing also revised the flight control software to limit the rate of elevator feel reduction with drops in airspeed. This will specifically allow the column to stay at a higher feel force to mitigate large and abrupt unintentional pitch inputs.

Safety message

In this case, the crew showed a high level of professionalism in response to a weather related event. The crew demonstrated high levels of communication and coordination, promptly applied checklists and procedures.

The ATSB brings to the attention of all flight crews, the importance of following documented procedures and directives when encountering weather related events.

The occurrence

On 21 December 2015, a Boeing 787-8 (B787) aircraft, registered VH-VKE, departed Melbourne, Australia on a scheduled passenger transport service to Singapore. The flight, operating as Jetstar Flight 07, departed at 0140 UTC (1240 local time)¹. At 0550 UTC, the aircraft was in cruise, being operated at flight level² (FL) 400. The first officer was the pilot flying (PF) and autopilot and autothrottle were engaged.

At the date of this occurrence an airworthiness directive (AD/B787/2013-24-01) relating to reducing the risk of engine icing was in effect, requiring avoidance of ice crystal icing³ conditions. As such, weather information with relevant en route icing conditions was used by the operator for the purposes of flight planning. In accordance with the AD, the crew manoeuvred around any observed weather conditions that had potential to cause icing to the engines.

Approaching waypoint CURLY, about 250 NM north of Darwin, Australia, the crew reported that a green coloured⁴ area, with magenta⁵ patches appeared ahead on their weather radar. This area was too close to avoid.

As a precaution the crew activated the seat-belt light. The aircraft entered an area of light turbulence which then increased to moderate. Concurrently with the increase in turbulence the crew noticed erratic airspeed indications on both PFDs, the autopilot disconnected and multiple EICAS⁶ messages were displayed including AIRSPEED UNRELIABLE and FLIGHT CONTROL MODE. The FLIGHT CONTROL MODE annunciation indicated that the aircraft flight control system had reverted to secondary mode⁷.

Shortly after the event, the captain took over the pilot flying role and the crew conducted the AIRSPEED UNRELIABLE checklist. The captain reported that this was a high workload situation and effective communication and coordination with the first officer greatly assisted the procedure.

The crew maintained an airspeed by setting a pitch angle and thrust level, as indicated in the applicable quick reference handbook table. Through comparison with this table, the crew were also able to identify the most accurate airspeed indication. The crew reported that at this stage it appeared that all indications had returned to normal.

The aircraft was 4 hours into an 8 hour journey, latched in secondary mode and could only be flown manually. Based on this, a decision was made to divert to Darwin, Northern Territory.

After jettisoning fuel to reduce the aircraft weight to maximum landing weight, the crew requested a straight-in approach and made an uneventful landing at Darwin airport.

Weather

A detailed meteorological analysis of the time and location of this event was conducted by the aircraft manufacturer's specialists. The analysis showed that the area in question contained

¹ Coordinated Universal Time (UTC): the time zone, equivalent to GMT, used for aviation. Local time zones around the world can be expressed as positive or negative offsets from UTC.

² Flight level: at altitudes above 10,000 ft. in Australia, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 370 equates to 37,000 ft.

³ At temperatures below freezing near convective weather, the aircraft can encounter visible moisture made up of high concentrations of small ice crystals.

⁴ The aircraft's weather radar detected precipitation droplets. In simple terms, black indicated minimal rainfall, green indicated light rainfall, yellow is moderate rainfall and red indicated heavy rainfall.

⁵ Magenta indicated turbulence.

⁶ EICAS = Engine indicating and crew alerting system.

⁷ Secondary mode: a mode of the flight control system with less automated functions and protections available. More detail is contained in the *Airspeed indication System description* section.

convective weather related to northern Australia’s monsoon season. These environmental conditions were highly conducive to ice crystal icing.

Airspeed indication system description

The B787 aircraft incorporated a pitot-static air-data reference system (ADRS), consisting of three independent pitot-static sensors. The sensed values from all three systems were input to a fault detection system that provided an airspeed value to the primary flight displays. This value was termed the *voted airspeed*.

The B787 also computed an angle of attack, synthetic airspeed (AOA speed) value that was available to the flight crew. This speed was derived from angle of attack and inertial data. Significant disparities between voted airspeed and AOA speed alerted the crew via AIRSPEED UNRELIABLE and the autopilot disconnecting.

If voted airspeed dropped to a specific threshold level, a reversion to a secondary flight control occurred. In secondary mode, the following functions of the flight control system were no longer available:

- Autopilot
- Auto speedbrakes
- Envelope protection
- Gust suppression
- Pitch compensation
- Roll/yaw asymmetry compensation
- Tail strike protection

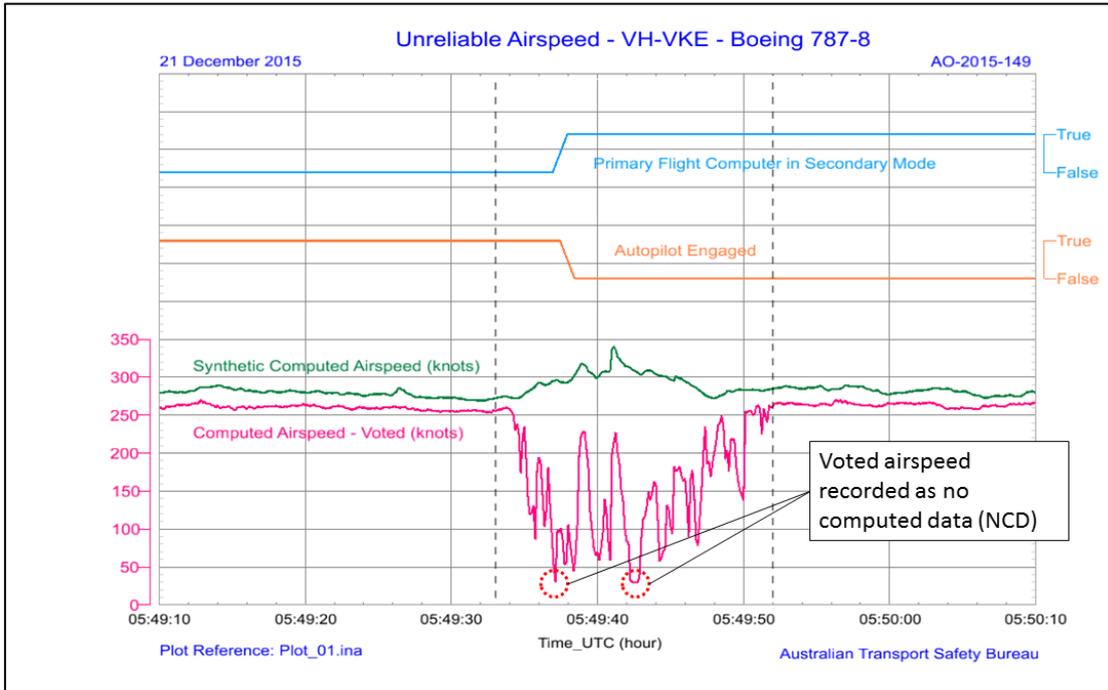
Elevator and rudder inputs are also more sensitive at some airspeeds, and yaw damping⁸ is degraded. For the conditions of this event, secondary mode is a latched condition and once activated, normal mode can only be re-instated on the ground.

Flight data

Flight data from the occurrence shows that the voted airspeed value became erratic for approximately 17 seconds. The voted airspeed values deviated significantly below the independent AOA speed calculated by the aircraft flight computer. As indicated in Figure 1, the voted airspeed was NCD for more than 0.1 seconds twice throughout the event.

⁸ A yaw damper is a device, independent of the autopilot system that applies rudder correction in order to reduce the lateral oscillations of an aircraft motion, with both rolling and yawing components (Dutch roll).

Figure 1: Graphical representation of flight data



Source: ATSB

This figure illustrates the discrepancy between the recorded values of voted airspeed and synthetic AOA speed. Within 5 seconds of the diverging values the autopilot and flight computer mode reversion had occurred. The airspeed disagreement lasted for a total of around 17 seconds.

Related occurrences

ATSB occurrence database

A review of the ATSB’s occurrence database between 2006 and 2016 found 11 other occurrences involving high capacity air transport category aircraft experiencing pitot-static system icing. None of these occurrences involved B787 aircraft.

Overseas occurrences

On 13 March 2014, a B787 operator en route to RJNK (Komatsu Airport) reported a severe turbulence event at FL290 and the Flight Control system reverted to secondary mode. Review of flight data was conducted and showed that, the voted airspeed dropped below 30 knots for 0.25 seconds which caused the system to revert to secondary mode. Four minutes later, the crew (following published procedures) cycled the Primary Flight Computers (PFC) disconnect switch and were able to regain Normal mode for the remainder of the flight. Weather conditions were identified as the likely contributor to the occurrence.

On 12 May 2015, during the cruise phase of flight, a B787 operator experienced a reversion to secondary mode for the remainder of the flight. The aircraft continued to its final destination and the landing was uneventful. Weather conditions were identified as the likely contributor to the occurrence.

Safety analysis

Reasons for erratic airspeed indications

The weather analysis provided by the aircraft manufacturer's meteorological specialists found that the erratic airspeed values likely resulted from ice crystal icing of the pitot-static systems. In this instance the icing affected the voted airspeed values for approximately 17 seconds.

Although there are three independent pitot-static systems for determining computed airspeed, adverse environmental conditions, as encountered during this flight, can affect all three simultaneously. On the B787, the synthetic AOA speed allows an independent source of airspeed as a comparison in order to validate the voted airspeed.

Once the airspeed values returned to normal, the ongoing flight was affected by the reversion and latching of the flight control computer to secondary mode.

Secondary mode reversion

A drop in recorded airspeed to, or below, a threshold level is referred to as a No Computed Data (NCD) state. Throughout the recorded airspeed fluctuations, there were two occasions where the value of voted airspeed went NCD for a sufficient time to revert the flight control system to secondary mode.

Boeing has taken action to revise the software in the flight control computer related to the secondary mode reversion. This revision has increased the time required in an NCD state to revert to secondary mode.

FAA Airworthiness directives

The FAA published an airworthiness directive (AD-2016-07-10) to advise crew not to make large magnitude abrupt control inputs as a response to sudden unrealistic drop in displayed airspeed at high actual airspeed. Abrupt control inputs in this condition could exceed the structural capability of the aircraft.

As a subsequent measure to the FAA AD, Boeing have revised the flight control software to limit the rate of elevator feel reduction, thereby reducing the risk of over controlling the aircraft at high speed.

Even though AD-2016-07-10 was published after this event, the crew actions were consistent with the directive in that they did not make any large changes to the control inputs.

Findings

From the evidence available, the following findings are made with respect to the erratic airspeed indications and subsequent flight control mode reversion on a Boeing 787-8, registered VH-VKE that occurred 250NM north of Darwin on 21 December 2015. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factors

- The aircraft entered a region of high ice water content which caused icing of the three independent pitot sources and anomalous airspeed indications.
- Short duration anomalous airspeed indications caused the flight control computer to transition to secondary mode. In secondary mode, the autopilot and some auto-flight protections were unavailable to the flight crew.

General details

Occurrence details

Date and time:	21 December 2015 – 1523 CST	
Occurrence category:	Serious Incident	
Primary occurrence type:	Unreliable Airspeed	
Location:	450 km north of Darwin, Northern Territory, Australia	
	Latitude: 11° 14.57' S	Longitude: 128° 39.63' E

Aircraft details

Manufacturer and model:	The Boeing Company 787-8	
Year of manufacture:	2014	
Registration:	VH-VKE	
Operator:	Jetstar Airways	
Serial number:	36230	
Type of operation:	Air Transport High Capacity	
Persons on board:	Crew – 10	Passengers – 292
Injuries:	Crew – 0	Passengers – 0
Damage:	None	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Flight data
- Flight crew interviews
- Jetstar operational documentation (Quick reference handbook, flight crew operations manual)
- Boeing safety analysis results.

Submissions

Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the Australian Transport Safety Bureau (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, Jetstar Airways, The Boeing Company and the Civil Aviation Safety Authority.

Submissions were received from The Boeing Company and the Civil Aviation Safety Authority. 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 operations involving the travelling public.

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.

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