Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation
AO-2009-065
Final

Unreliable airspeed indication 710 km south of Guam 28 October 2009 VH-EBA Airbus A330-202

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Figure 1: Google Earth

Figure 3: Japanese Meteorological Agency (obtained for the ATSB by the US National Transportation Safety Board)

Figure 5: Adapted from the Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile

Abstract

On 28 October 2009, an Airbus A330-202 (A330) aircraft, registered VH-EBA (EBA), was being operated as Jetstar flight 12 on a scheduled passenger service from Narita, Japan to Coolangatta, Australia. Soon after entering cloud at 39,000 ft, there was a brief period of disagreement between the aircraft's three sources of airspeed information. The autopilot, autothrust and flight directors disconnected, a NAV ADR DISAGREE caution message occurred, and the flight control system reverted to alternate law, which meant that some flight envelope protections were no longer available. There was no effect on the aircraft's flight path, and the flight crew followed the operator's documented procedures. The airspeed disagreement was due to a temporary obstruction of the captain's and standby pitot probes, probably due to ice crystals. A similar event occurred on the same aircraft on 15 March 2009.

The rate of unreliable airspeed events involving the make of pitot probes fitted to EBA (Goodrich 0851HL) was substantially lower than for other probes previously approved for fitment to A330/A340 aircraft. However, both of the events involving EBA occurred in environmental conditions outside those specified in the certification requirements for the pitot probes. The French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) has recommended the European Aviation Safety Agency (EASA) to review the certification criteria for pitot probes in icing environments.

At the time of the occurrence, most of the operator's A330 pilots had not received unreliable airspeed training. Most of these pilots had transferred from the operator's A320 fleet, and the third-party training provider had not included the topic in its A320 endorsement training program, even though it was included in the aircraft manufacturer's recommended program since 2003.

The operator identified the problem and included unreliable airspeed in its recurrent training program for the A320 from May 2009 and the A330 from October 2009. The training provider included the topic in its endorsement program from July 2010. The operator, training provider and the Civil Aviation Safety Authority all initiated safety action to minimise the likelihood of similar problems in the future.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The Bureau 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 safety factors related to the transport safety matter being investigated. The terms the ATSB uses to refer to key safety and risk concepts are set out in the next section: Terminology Used in this Report.

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.

TERMINOLOGY USED IN THIS REPORT

Occurrence: accident or incident.

Safety factor: an event or condition that increases safety risk. In other words, it is something that, if it occurred in the future, would increase the likelihood of an occurrence, and/or the severity of the adverse consequences associated with an occurrence. Safety factors include the occurrence events (e.g. engine failure, signal passed at danger, grounding), individual actions (e.g. errors and violations), local conditions, current risk controls and organisational influences.

Contributing safety factor: a safety factor that, had it not occurred or existed at the time of an occurrence, then either: (a) the occurrence would probably not have occurred; or (b) the adverse consequences associated with the occurrence would probably not have occurred or have been as serious, or (c) another contributing safety factor would probably not have occurred or existed.

Other safety factor: a safety factor identified during an occurrence investigation which did not meet the definition of contributing safety factor but was still considered to be important to communicate in an investigation report in the interests of improved transport safety.

Other key finding: any finding, other than that associated with safety factors, considered important to include in an investigation report. Such findings may resolve ambiguity or controversy, describe possible scenarios or safety factors when firm safety factor findings were not able to be made, or note events or conditions which 'saved the day' or played an important role in reducing the risk associated with an occurrence.

Safety issue: a safety factor that (a) can reasonably be regarded as having the potential to adversely affect the safety of future operations, and (b) is a characteristic of an organisation or a system, rather than a characteristic of a specific individual, or characteristic of an operational environment at a specific point in time.

Risk level: The ATSB's assessment of the risk level associated with a safety issue is noted in the Findings section of the investigation report. It reflects the risk level as it existed at the time of the occurrence. That risk level may subsequently have been reduced as a result of safety actions taken by individuals or organisations during the course of an investigation.

Safety issues are broadly classified in terms of their level of risk as follows:

- **Critical** safety issue: associated with an intolerable level of risk and generally leading to the immediate issue of a safety recommendation unless corrective safety action has already been taken.
- **Significant** safety issue: associated with a risk level regarded as acceptable only if it is kept as low as reasonably practicable. The ATSB may issue a safety recommendation or a safety advisory notice if it assesses that further safety action may be practicable.
- **Minor** safety issue: associated with a broadly acceptable level of risk, although the ATSB may sometimes issue a safety advisory notice.

Safety action: the steps taken or proposed to be taken by a person, organisation or agency in response to a safety issue.

FACTUAL INFORMATION

History of the flight

On 28 October 2009, an Airbus A330-202 (A330) aircraft, registered VH-EBA (EBA), departed Narita, Japan on a scheduled passenger transport service to Coolangatta, Australia. The flight, operating as Jetstar flight 12, departed at 1155 UTC (2055 local time).[1] There were 11 crew and 203 passengers on board.

The aircraft was being operated at flight level (FL)[2] 390. The first officer was the handling pilot, and autopilot 2 and autothrust were engaged.

The flight crew reported that they had been manoeuvring around cloud build-ups that night for several minutes and had seen lightning in areas off to both sides of the aircraft. The last 'paint' they could see ahead on the aircraft's weather radar was an area of light green[3], viewed on the 40 NM (74 km) scale. They did not anticipate any turbulence, so they decided to fly through the cloud. However, they selected the seat belt sign ON as a precaution. Soon after entering the cloud, there was a large amount of St. Elmo's fire[4] present on the aircraft's windscreen. The flight through the cloud was mostly smooth, and no turbulence was experienced.

The crew reported that, about 1 minute after the St. Elmo's fire commenced, they noticed a rapid and momentary drop in the airspeed indication on the captain's primary flight display (PFD). They did not notice any changes in the first officer's or standby airspeed indications. The flight data recorder (FDR) showed that the decrease in the captain's airspeed indication occurred at 1537:17. The airspeed decreased to about 50 kts before returning to its previous value of about 250 kts within 5 seconds. Fault information recorded by various aircraft systems indicated that there was also a brief decrease in the standby airspeed indication at about this time.

Immediately following the indicated airspeed decrease, the autopilot, autothrust and flight directors automatically disconnected. In addition, the flight control system reverted from normal law to alternate law (see subsequent discussion titled *Flight control system*), and there was a NAV ADR DISAGREE caution message displayed on the electronic centralized aircraft monitor (ECAM).[5] Other caution messages

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1 The 24-hour clock is used in this report to describe the time of day, Coordinated Universal Time (UTC), as particular events occurred.

2 Level of constant atmospheric pressure related to the datum of 1013.25 hPa, expressed in hundreds of feet. FL 390 equated to 39,000 ft above mean sea level (AMSL).

3 The aircraft's weather radar detected precipitation droplets. In simple terms, black indicated minimal rainfall, light green indicated light precipitation, yellow indicated moderate rainfall, and red indicated heavy rainfall. The radar returns were dependent on many factors; for example, water droplets were more easily detected than ice particles.

4 St Elmo's fire is a luminous plasma, which results from a build up of electrostatic potential. It can be seen at the front of an aircraft during certain types of weather conditions, such as the convective activity associated with thunderstorms.

5 The ECAM provides information on the status of the aircraft and its systems, including warning and caution messages and relevant actions required by the crew.

were also displayed to the crew during this period. However, the indicated airspeed fluctuations had no effect on the aircraft's flight path.

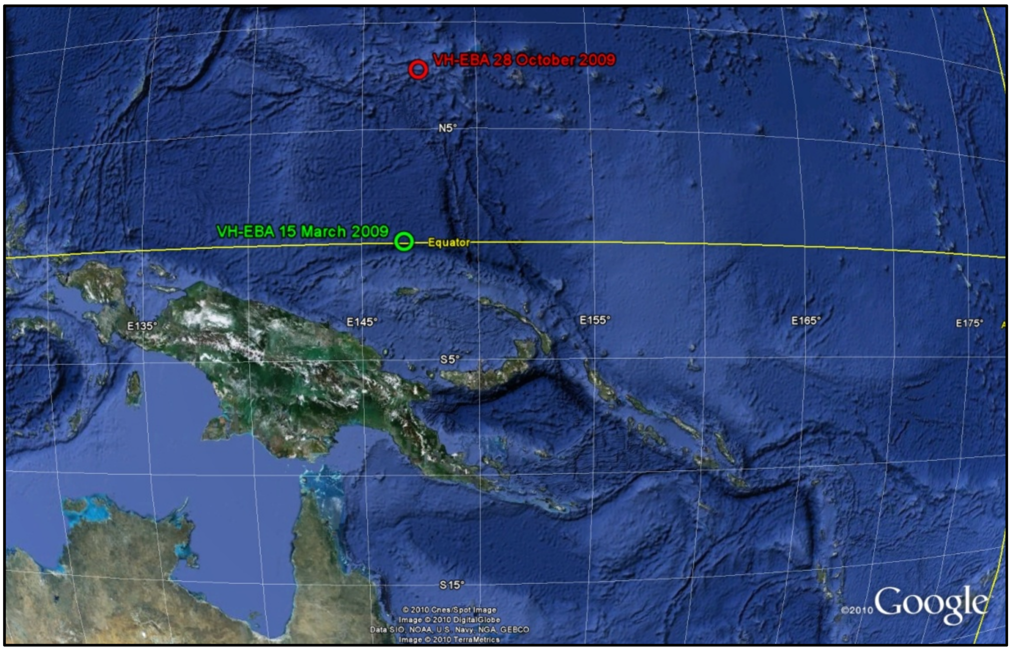
Consistent with the operator's procedures for responding to an unreliable airspeed indication and the ECAM messages they had received, the crew confirmed that the attitude and thrust settings were normal, and they again checked the captain's, first officer's and standby airspeed indicators; no disagreement was noted. They then responded to the THRUST LOCK ECAM message associated with the autothrust disconnection[6], and re-engaged autopilot 2 and the autothrust. Shortly after, autopilot 2 and autothrust automatically disconnected a second time. The crew then engaged autopilot 1 and autothrust.

After they were satisfied that all parameters were normal, the crew reviewed the ECAM messages. The only ECAM message requiring a crew response was the NAV ADR DISAGREE message. The first part of the associated procedure required the crew to check the airspeed information on the captain's and first officer's PFDs and on the standby airspeed indicator. As the three speeds were still in agreement, no further action was required.

The crew reported that they closely monitored the airspeed indications for the remainder of the flight and noticed no discrepancies. They also conducted a detailed review of their situation and concluded that they did not need to take any other precautions. The aircraft landed at Coolangatta at 2017 (0617 local time).

Subsequent analysis of recorded information showed that the incident occurred 710 km south of Guam at the position 7.63° north and 147.48° east. The location of this and a previous, similar event involving the same aircraft (see *EBA, 15 March 2009*) are shown at Figure 1.

Figure 1: Location of unreliable airspeed events involving EBA



6 Thrust levels are locked after an involuntary autothrust disconnection until the thrust levers are moved. The THRUST LOCK caution message will appear every 5 seconds until the thrust levers are moved.

Aircraft information

Type/model	Airbus A330-202
Registration	VH-EBA
Serial number	0508
Date of manufacture	2002
Date first registered in Australia	November 2002
Date first registered with operator	February 2007
Flight hours	27,633

Airspeed measurement

The A330 had three independent systems for calculating and displaying airspeed information: (1) captain, (2) first officer, and (3) standby systems. Each system used its own pitot probe, static ports, air data modules (ADMs), air data inertial reference unit (ADIRU), and airspeed indicator.

Airspeed is measured by comparing total air pressure (Pt)[7] and static air pressure (Ps). On the A330, Pt was measured using a pitot probe, and Ps was measured using two static ports. A separate ADM was connected to each pitot probe and each static port, and it converted the air pressure from the probe or port into digital electronic signals.

Each pitot probe consisted of a tube that projected several centimetres out from the fuselage, with the opening of the tube pointed forward into the airflow. The tube had drain holes to remove moisture, and it was electrically heated to prevent ice accumulation during flight.

In addition to the pitot probe and static ports, the aircraft also had two total air temperature (TAT) probes that were used for determining the static (or outside) air temperature (SAT)[8], and three angle of attack sensors. The locations of the aircraft's pitot probes and TAT probes are shown in Figure 2.

All of the probes, ports and sensors were electrically heated, and the heating was automatically activated whenever the aircraft was in flight. Three independent probe heat computers controlled the electrical heating of the captain's, first officer's, and standby systems. Each probe heat computer monitored the heating current and triggered a warning if predetermined thresholds were reached.

The aircraft had three ADIRUs, and each ADIRU obtained data from a different set of sensors. For example, the captain's pitot probe provided information to ADIRU 1, the first officer's pitot probe provided information to ADIRU 2, and the standby pitot probe provided information to ADIRU 3.

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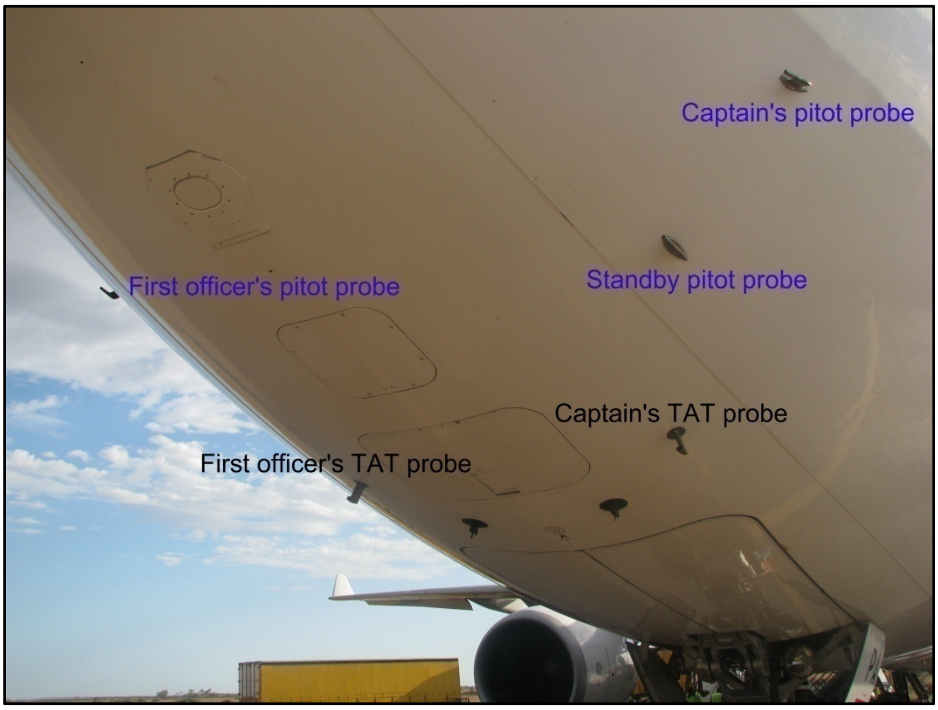
7 Pt is the sum of static (or outside) air pressure and pressure due to relative airspeed.

8 TAT is the sum of SAT and heating due to relative airspeed. TAT and Mach were used for calculating SAT and true airspeed (or the actual speed of the aircraft through the air mass in which it is flying).

Figure 2: Location of pitot and TAT probes on an A330



Each ADIRU had two separate parts: the inertial reference (IR) part, and the air data reference (ADR) part. The ADR calculated parameters such as SAT, TAT, angle of attack, altitude and airspeed. Airspeed was calculated in terms of computed airspeed (CAS) and Mach, with calculations made eight times per second.[9] Computed airspeed was displayed on the captain's PFD (from ADIRU 1), the first officer's PFD (from ADIRU 2), and the standby airspeed indicator (from ADIRU 3).

The ADIRUs sent the calculated parameters to other aircraft systems, including the flight management, guidance and envelope system (FMGES) and the electrical flight control system (EFCS).

The operator's A330 *Flight Crew Training Manual*, which was based on the aircraft manufacturer's manual, included the following statement:

> The most probable reason for erroneous airspeed and altitude information is obstructed pitot tubes or static sources. Depending on the level of obstruction, the symptoms visible to the flight crew will be different. However, in all cases, the data provided by the obstructed probe will be false. Since it is highly unlikely that [all of] the aircraft probes will be obstructed at the same time, to the same degree and in the same way, the first indication of erroneous airspeed/altitude data available to flight crews, will most probably be a discrepancy between the various sources.

Flight guidance system

The flight guidance system used two independent flight management, guidance and envelope computers (FMGECs). The flight guidance part of each computer

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9 Mach is the ratio of true airspeed to the speed of sound. It was derived solely from Pt and Ps. Computed airspeed (in kts) was based on Pt and a value of Ps which was corrected for static source error.

controlled the autopilot, autothrust and flight director (FD) functions. FMGEC 1 controlled autopilot 1 and FMGEC 2 controlled autopilot 2. Flight director 1 displayed control orders from FMGEC 1 on the captain's PFD and flight director 2 displayed control orders from FMGEC 2 on the first officer's PFD.

Both FMGECs continuously monitored the altitude, computed airspeed and Mach outputs from all three ADRs. If the computers noted a difference between the outputs of one ADR and the other two ADRs that was above a predetermined threshold, then that ADR was rejected (and the auto flight functions remained engaged). If the FMGEC in command (for example, FMGEC 2 for autopilot 2) detected a difference above the threshold between the two remaining ADRs, the autopilot, autothrust and associated flight director were automatically disconnected. If the FMGEC not in command detected a difference, then the associated flight director was disconnected.

Each flight director automatically re-engaged when its associated FMGEC detected that at least two ADR values were again valid and consistent. The autopilot and autothrust needed to be re-engaged by the flight crew.

Flight control system

The Airbus A330 had fly-by-wire flight controls. The aircraft's flight control surfaces were electrically controlled and hydraulically activated, and flight control computers processed pilot and autopilot inputs to direct the control surfaces as required. There were three flight control primary computers (FCPCs or PRIMs) and two flight control secondary computers (FCSCs or SECs).

The FCPCs continuously monitored outputs from the three ADIRUs. The median (voted) value of each parameter was compared to each individual value. If the difference was above a predetermined threshold for a predetermined confirmation time, then the associated part of that ADIRU (IR or ADR) was rejected and the two remaining sources were used for flight control purposes.

A NAV ADR DISAGREE caution message occurred when there were inconsistencies between the three sources of an ADR parameter used by the FCPCs. The message occurred if one source was different to the other two over a 10-second period, and there were then differences between the two remaining sources.

The flight control system operated according to normal, alternate or direct control laws. Under normal law, the computers prevented the exceedance of a predefined safe flight envelope. If various types of aircraft system problems were detected, then the control law reverted to alternate law. Under alternate law, some of the protections were not provided or were provided with alternate logic. For example, automatic angle of attack protection and overspeed protection were not provided in alternate law. Under direct law, no protections were provided and control surface deflection was proportional to sidestick and pedal movement by the flight crew.

The flight control system reverted to alternate law when a decrease in the median (voted) value of computed airspeed dropped by more than 30 kts in 1 second. After 10 seconds, the voted value was compared to the voted value before the airspeed drop. If the difference was less than 50 kts, then the flight control system returned back to normal law.

Recorded information

Recorded data from the flight was obtained from the digital flight data recorder (FDR) and the digital ACMS[10] recorder (DAR). Figure 3 provides a summary of the key information obtained from the recorders. A summary of the key events from the recorders and other sources is presented in Table 1.

The recorders only sampled airspeed information from ADIRU 1, with values sampled four times per second. The data showed that, at 1537:17, the captain's computed airspeed started to rapidly drop. It reached a level of about 50 kts (Mach 0.17) for 4 seconds, and then returned to its previous level of about 250 kts (Mach 0.80) at 1537:22. No other anomalies were noted in the captain's airspeed data.

During the period of the drop in computed airspeed (1537:17 to 22), there were also changes in the values of altitude, TAT and SAT that were displayed to the crew and recorded by the FDR and DAR. The changes were consistent with the effects of the change in airspeed values and did not indicate any change in the actual value of the parameters. More specifically:

- Recorded altitude decreased from 39,000 ft to 38,700 ft. The ADIRU provided a correction to altitude, which was a function of airspeed.
- Recorded TAT[11] decreased from about -19 °C to -24 °C. At low airspeeds, the ADIRU applied a correction to TAT values.
- Recorded SAT increased from -48 °C to -25 °C. SAT was derived from TAT and Mach, and the SAT increase was due to the erroneous Mach values.

A temporary drop in airspeed, together with these minor changes in related variables, was consistent with the pitot probe being temporarily obstructed.

The second disconnection of the flight guidance functions at 1538:15 indicated that there was a second period of disagreement between the airspeed values. Because autopilot 2 was in command during the first autopilot disconnection (1537:19), FMGEC 2 had 'latched'[12] a rejection of an ADR (probably ADR 1). Later, when there was a disagreement between the two other ADRs, the autopilot, autothrust and flight director 2 were disconnected. The recovery of the flight director soon after indicated that the disagreement lasted about 2 seconds.[13]

At about 1538:00 and 1539:16, the TAT values increased rapidly towards 0 °C. This behaviour was consistent with the captain's TAT probe being temporarily obstructed.

There were no stall warnings or anomalies with angle of attack data during the flight.

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10 ACMS: Aircraft Condition Monitoring System.

11 The FDR did not record TAT, but the DAR did sample this parameter from the captain's TAT probe.

12 In this context, 'latched' means that the fault condition remained set for the remainder of the flight.

13 FMGEC 1 had not latched the initial rejection of an ADR because it was not in command at the time. Therefore, when the second disagreement occurred, it had two ADRs available and FD 1 was not disconnected.

Figure 3: Graphical representation of relevant parameters

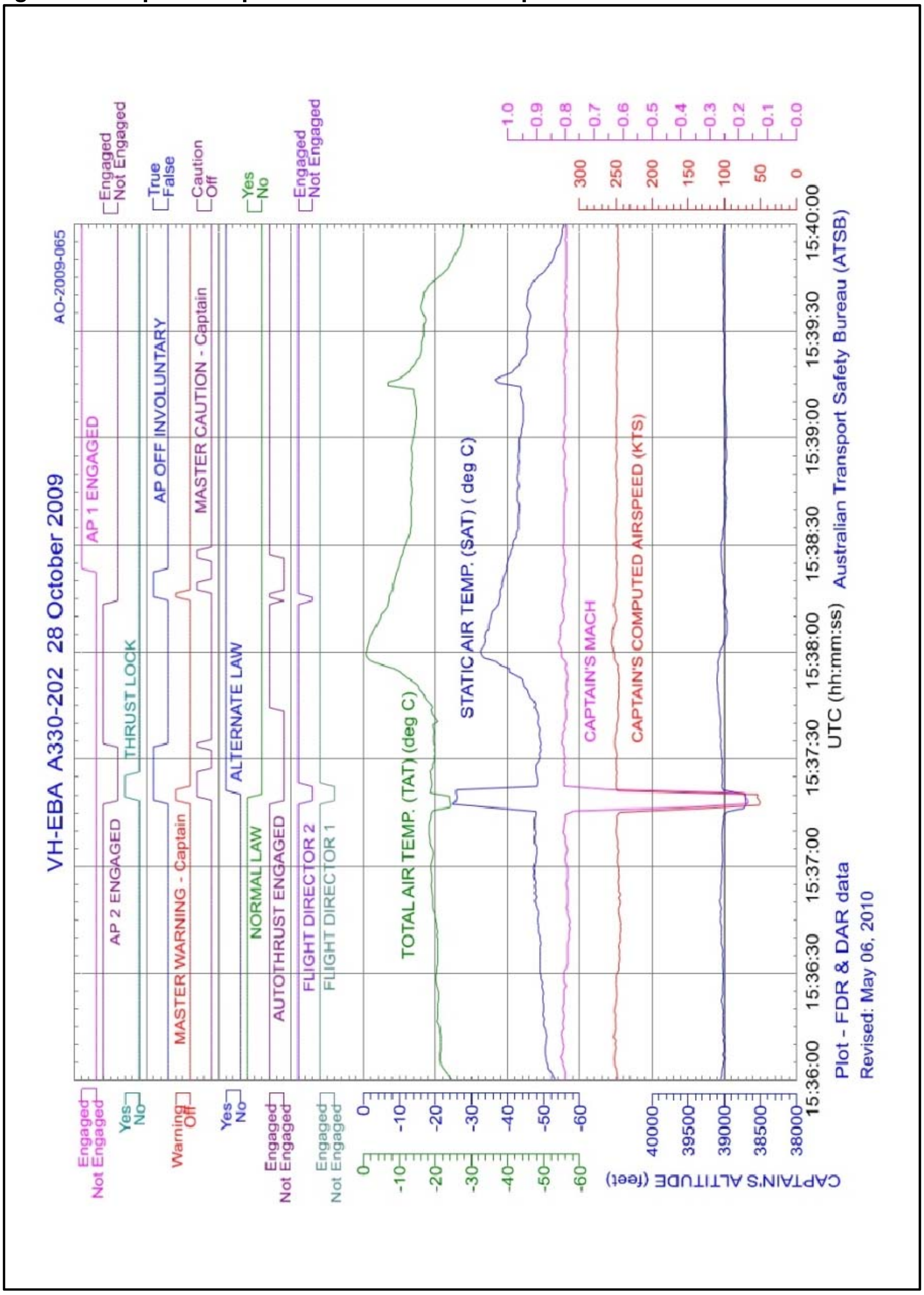

Table 1: Sequence of airspeed-related events[14]

Time	Event
1537:17	captain's airspeed started to decrease
1537:18*	ADIRU 1 built-in test equipment (BITE) reported a problem with the captain's airspeed
1537:19	autopilot 2, autothrust, flight directors 1 and 2 disconnected
1537:21	flight controls reverted to alternate law (for the rest of the flight)
1537:22	captain's airspeed recovered back to normal values (about 250 kts)
1537:24*	ADIRU 3 BITE reported a problem with standby airspeed
1537:24	flight directors 1 and 2 re-engaged (indicating that at least two ADRs were again consistent)
1537:27	THRUST LOCK inactive (indicating that the crew responded to the THRUST LOCK message)
1537:35	autopilot 2 re-engaged by the crew
1537:45	autothrust re-engaged by the crew
1538:12*	FMGEC BITE reported that ADR 3 was rejected at about this time
1538:15	autopilot 2, autothrust, and flight director 2 disconnected
1538:17	flight director 2 re-engaged
1538:18	autothrust disconnected
1538:24	autopilot 1 engaged by the crew
1538:28	autothrust re-engaged by the crew

Maintenance system messages

A post flight report (PFR) was produced by the aircraft's central maintenance computer at the end of a flight. It contained fault information received from other aircraft systems' built-in test equipment (BITE). PFR messages were of two main types:

- cockpit effect messages, which reflected indications presented to the flight crew on the ECAM or other displays
- maintenance fault messages, which provided information to maintenance personnel on the status or functioning of aircraft systems.

A PFR only provided general information. To obtain more detailed information regarding the PFR messages, BITE data needed to be obtained from the relevant systems. Following the 28 October 2009 flight, BITE data was obtained from the aircraft's FMGES, EFCS and ADIRUs.

The PFR for the flight contained several cockpit effect messages related to the unreliable airspeed event. Table 2 shows the cockpit effect messages associated with the FMGES and the EFCS. The order of the messages in the table is not necessarily the order that they occurred.

[14] Times marked with a '*' indicate the event occurred at that time or within the next 6 seconds.

Table 2: Relevant cockpit effect messages from the PFR

System	Cockpit effect message[15]	Meaning
FMGES	AUTO FLT AP OFF	autopilot disconnected
FMGES	AUTO FLT A/THR OFF	autothrust disconnected
FMGES	FLAG ON CAPT PFD FD	captain's flight director disconnected
FMGES	FLAG ON F/O PFD FD	first officer's flight director disconnected
FMGES	FLAG ON CAPT PFD SPD LIMIT	characteristic speeds no longer displayed on the captain's primary flight display
FMGES	FLAG ON F/O PFD SPD LIMIT	characteristic speeds no longer displayed on the first officer's primary flight display
FMGES	AUTO FLT REAC W/S DET FAULT	reactive windshear detection system no longer available
EFCS	F/CTL ALTN LAW	reversion to alternate law
EFCS	F/CTL RUD LIM FAULT	rudder travel limit function lost[16]
EFCS	NAV ADR DISAGREE	one ADR rejected by the EFCS and then disagreement between the other two ADRs

The BITE data from the EFCS included a message reporting that a speed decrease of more than 30 kts in 1 second was detected on at least two airspeeds. EFCS BITE messages were only recorded to the nearest minute, but it was very likely that this event occurred at the same time that the flight controls reverted to alternate law (1537:21).

The BITE data from the FMGES and the ADIRUs recorded fault messages to the nearest tenth of a minute (6-second period). In addition to fault messages associated with the first disconnection of the flight guidance functions, the FMGES BITE included a fault message reporting that the FMGECs rejected ADR 3 at some time between 1538:12 and 1538:18. This message was consistent with the autopilot 2 disconnection at 1538:15.

The PFR contained maintenance fault messages for ADIRU 1 and ADIRU 3, but the ADIRU BITE data reported no fault messages indicating problems with the ADIRUs themselves. However, there were fault messages consistent with problems in the airspeed information provided to ADIRU 1 (between 1537:18 and 1537:24) and ADIRU3 (between 1537:24 and 1537:30) by the pitot probes or associated ADMs. Another fault message associated with ADIRU 1 (but not ADIRU 3) indicated that, in between 1537:18 and 1537:24, Pt was lower than Ps.

The FDR data showed that the flight control system reverted to alternate law at 1537:21 and remained in alternate law for the remainder of the flight. Based on the system's logic, this meant that the median airspeed value must have been at least 50 kts below the normal value at about 1537:31. Although the ADIRU BITE data indicated that there was probably a problem with the airspeed data from ADIRU 3,

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15 Most of these messages were displayed on the ECAM. 'Flag' messages were displayed on a pilot's PFD. When a flag was displayed there was no associated ECAM message.

16 The rudder travel limit unit restricted the maximum allowable rudder deflection as a function of airspeed. This message was consistent with the flight control system switching to and then maintaining alternate law.

it was not possible to determine which of the other two airspeed values was affected at that time.

There were no PFR messages indicating any problems associated with the probe heating systems.

Component examinations

Maintenance records

A review of maintenance records identified that the aircraft had experienced another unreliable airspeed occurrence on 15 March 2009 (see the subsequent discussion titled *EBA, 15 March 2009*). Other than that occurrence, and the replacement of pitot probe 2 in July 2007 due to lightning damage, no other problems associated with the aircraft's airspeed measurement systems were noted.

Pitot probes

The aircraft was fitted with Goodrich model 0851HL pitot probes. Probes 1 (serial number 212943) and 3 (213284) were both manufactured in March 2002 and had been on the aircraft since its initial operations in 2002. Probe 2 (216654) had been on the aircraft since July 2007.

Following the 28 October 2009 event, the operator's engineering personnel completed maintenance tasks to flush the pitot and static pressure lines, and do a low range leak check of the pitot and static systems. No problems were identified.

Probes 1 and 3 were removed from the aircraft by the operator and sent to the probe manufacturer for examination. The manufacturer reported that the probes were subject to its applicable acceptance test procedure, which focussed primarily on the de-icing heater properties. Both probes successfully passed all testing.

In addition, the probe manufacturer conducted a detailed visual inspection of the probes, and no problems were noted internally. The pitot inlet and outside surface of the sensing head exhibited evidence of corrosion, which was typical for probes of the same age. The probes were also examined using real time X-Ray, and no anomalies were found.

Air data modules

The aircraft was fitted with Thales ADMs, part number 87232329V03.
ADMs 1 and 3 had been connected to the respective pitot probes and installed in the aircraft since 2002. Following the occurrence, they were removed by the operator and sent to the ADM manufacturer for examination. Both modules were found to have drifted slightly out of the required calibration range. The manufacturer advised that such drift levels were normal given the age of the modules. The aircraft manufacturer advised that the drift levels equated to less than 1 kt in airspeed during the cruise.

ADIRUs

The aircraft was fitted with Northrop Grumman model LTN101 ADIRUs. ADIRU 1 had been on the aircraft since March 2009 and ADIRU 3 since 2002. The operator sent ADIRUs 1 and 3 to the manufacturer to download BITE data and conduct a standard manufacturer's test procedure. No faults with ADIRUs 1 and 3, relevant to the occurrence, were found during the testing.

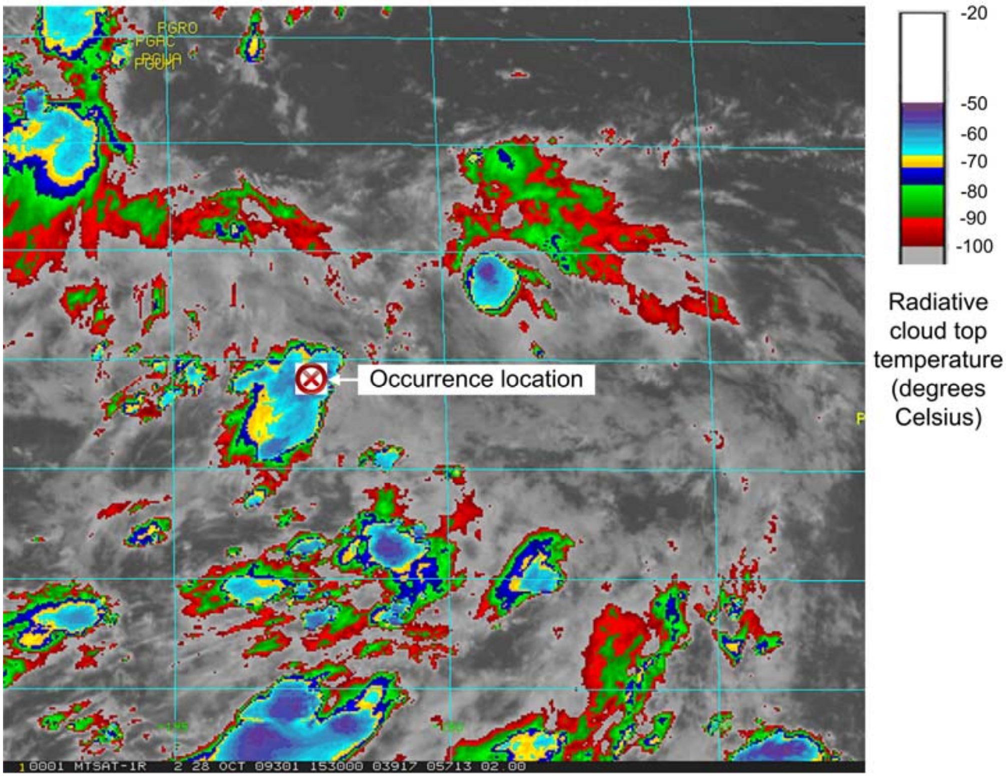
Probe heat computers

During the replacement of pitot probes 1 and 3 following the occurrence, an operational test was performed on all three probe heat computers. No faults were found.

Meteorological information

The forecasted weather conditions for the flight included isolated, embedded cumulonimbus clouds in the tropical regions, up to FL 540. An image taken at 1530 on 28 October 2009 by the Japanese Meteorological Agency's multi-functional transport satellite (MTSAT) is shown in Figure 4. The aircraft's position at 1537 is shown by the red cross.

Figure 4: Satellite image at 1530 on 28 October 2009



As indicated in the image (and a subsequent image taken at 1557), the aircraft was located within or under a large defined cluster of cumulonimbus clouds at the time of the event. The radiative cloud top temperature[17] at 1530 was -71.6 °C, which corresponded to cloud tops of over 47,000 ft.

As previously stated, the aircraft was operating at FL 390 (39,000 ft). Data from the FDR indicated that the SAT at the aircraft's location during the event was -48 °C and that the TAT was -19 °C. The FDR data also indicated that the aircraft did not encounter any significant turbulence during the event.

The crew reported that they observed no icing on the aircraft in the period before or during the event. As previously stated, the crew reported that the aircraft's weather radar only indicated an area of light green. The aircraft's weather radar system detects moisture in a horizontal plane ahead of the aircraft. The satellite images are based on temperature and provide a plan view of a broad area. Due to the differences in technology and viewing angle, the nature of the information available to the crew would generally be different to that detected by the satellite.

Flight crew procedures

The operator's *Flight Crew Operations Manual* (FCOM) contained an 'abnormal'[18] procedure for responding to a NAV ADR DISAGREE message from the ECAM. The procedure required the crew to check the airspeed information on the three airspeed indicators. If they agreed, no further action was required. If there was a disagreement, the crew were required to apply the UNRELIABLE AIRSPEED INDIC [indication] / ADR CHECK PROC [procedure].

The UNRELIABLE AIRSPEED INDIC / ADR CHECK PROC was an abnormal procedure that was not displayed on the ECAM. The procedure's objectives were to enable the crew to identify and isolate the faulty airspeed source(s) and, if that was not successful, fly the aircraft until landing without any speed reference. The operator's *Flight Crew Training Manual* (FCTM) stated that the procedure should be applied in response to an ECAM message (such as NAV ADR DISAGREE or ANTI-ICE PITOT) or when the crew suspected erroneous indications.

The unreliable airspeed / ADR check procedure had three parts:

- Memory items.[19] A set of 'memory items' was to be used in situations where 'the safe conduct of the flight is impacted'. These actions included selecting the autopilot, flight directors and autothrust OFF, and actions for pitch, thrust, flaps, speed brakes and landing gear settings.
- Troubleshooting and isolation. The crew were required to review relevant information sources to identify the faulty airspeed system(s). If this was achieved and at least one ADR was selected ON and providing reliable information, the procedure was completed.

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17 The radiative cloud top temperature, derived from infrared satellite images, provides an indication of the height of the cloud tops.

18 Flight crew procedures are generally classified as 'normal', 'abnormal', or 'emergency'. Abnormal events are unpredicted events that affect the use of normal operating procedures by the crew.

19 Memory items are actions to be completed without referring to a reference. Only a small number of the operator's abnormal or emergency operations required memory items.

- Flight using pitch and thrust reference. In situations where the faulty airspeed sources could not be identified, one ADR was to be left on to provide stall warning protection. The crew were then required to use tables to select pitch angles and thrust settings appropriate for the aircraft's altitude and configuration.

The operator's NAV ADR DISAGREE and unreliable airspeed procedures were the same as the aircraft manufacturer's procedures.

Flight crew training

Endorsement training

There was no specific regulatory requirement for Australian operators to provide flight crew with training on unreliable airspeed situations, although the Civil Aviation Safety Authority (CASA) advised that it was normally covered as part of a pilot's endorsement (type rating).[20] Since April 2003, the aircraft manufacturer had included an unreliable airspeed exercise in its recommended training program for A330/A340 endorsements and A320 endorsements.

The operator of EBA did not provide initial endorsement training on the A330. Although some of its A330 pilots had received their A330 endorsements from other airlines, most of its A330 pilots had transferred from its A320 fleet. The operator had provided the transitioning pilots with cross crew qualification training from the A320 to the A330. This training was based on the manufacturer's recommended program and covered ADR faults and the ADR check procedure, but it did not specifically deal with unreliable airspeed situations.[21]

The operator also did not provide initial endorsement training to its A320 pilots; instead it contracted a third-party training provider (Alteon[22]) to endorse pilots that were either employed, or were going to be employed, on its A320 aircraft. The training provider advised that it had not included unreliable airspeed training as part of its A320 endorsement training program. Consequently, many of the operator's A320 and A330 pilots had not received unreliable airspeed training as part of their endorsement training on either aircraft, even though such training had been part of the aircraft manufacturer's recommended training program since April 2003.

Although it had access to the operator's procedures and training manuals, the training provider did not have a current copy of the aircraft manufacturer-recommended training program and related materials, or have direct access to current manufacturer documentation. The third-party training provider was part of another aircraft manufacturer's organisation, and its syllabus was based on a version obtained from an overseas division of its organisation.

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20 CASA advised that it would be impractical for it to have specific requirements for all types of unreliable events, and that there were other mechanisms in place to ensure such events were adequately addressed in training programs.

21 The manufacturer-recommended training program for the cross crew qualification from the A320 to the A330 did not include unreliable airspeed training, as it was already included in the manufacturer's recommended A320 endorsement training program.

22 Alteon subsequently changed its name to Boeing Training and Flight Services.

CASA initially approved the third-party training provider's A320 endorsement training program in July 2004, and it subsequently approved changes to the program. It advised that, when approving an initial endorsement training course, it assessed the course against the regulatory requirements. It also expected to see the aircraft manufacturer's course used as a benchmark for the applicant's course. When assessing amendments, the new proposed course would be compared to the previously-approved course.

CASA also advised that, when approving a training course, it did consider whether the training organisation had access to the aircraft manufacturer's training program and related materials. It noted that, in this case, the third-party training provider only provided services to contracting operators, and CASA's expectation was that the operator would provide the training provider with a current syllabus and related materials suitable for the operator's needs.

The operator reported that it was not aware of this expectation. It also stated that it could not provide the third-party training provider with the aircraft manufacturer's documentation due to the manufacturer's copyright restrictions. It also noted that the CASA approval to conduct the A320 endorsement training was held by the third-party training provider, not by the operator.

The operator advised that it conducted yearly observations of the training provider's instructors, and that it had asked the training provider to make changes to its training program over the years.[23] In July 2009, the operator received new versions of training materials from the aircraft manufacturer, and they subsequently conducted a comparison of the recommended program and the third-party training provider's program. Other than the absence of unreliable airspeed training, no material differences were found.

Previous ATSB investigations have noted that, under current regulatory arrangements, the relative responsibilities of operators and third-party training providers for training outcomes was unclear, and that CASA was developing legislative changes to address the situation.[24]

Recurrent training

In addition to initial endorsement training, the operator's flight crew received recurrent (cyclic) training sessions. The frequency that a topic was covered in the recurrent training program was based on regulatory requirements and the operator's assessment of training needs across the fleet. The operator conducted recurrent training for its A330 and A320 flight crew in a simulator twice every year.

Prior to 2009, the operator had not included unreliable airspeed training in its recurrent training program, although the training had included ADR faults. There

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23 The operator advised that the major change had been to increase the duration of the endorsement training course in 2007 for students with little or no previous jet aircraft experience. The regulator also advised that it was involved in the decision to expand the duration of the course, following an investigation into a complaint by a student.

24 For example, see ATSB aviation occurrence investigation AO-2007-044 (Go-around event, Melbourne Airport, Victoria, 21 July 2007, VH-VQT, Airbus Industrie A320-202) available at www.atsb.gov.au. This investigation involved the same operator and same third-party training provider.

was no Australian regulatory requirement to include unreliable airspeed training in recurrent training programs.

Following the Air France flight AF447 A330-200 accident on 1 June 2009 (see the subsequent discussion titled *Other unreliable airspeed events on A330/A340* aircraft), the European Aviation Safety Agency (EASA) issued Safety Information Bulletin 2009-17 (*Unreliable airspeed indication*) on 9 June 2009 recommending that operators 'ensure that flight crews have proper knowledge and proficiency' to detect, identify and appropriately respond to unreliable airspeed situations. The bulletin also stated that 'familiarisation with unreliable airspeed indication procedures should be provided through adequate training' and 'knowledge and proficiency should be checked on a regular basis'.

On 9 September 2009, the aircraft manufacturer issued a Flight Operations Telex (FOT) to all operators of A318/319/320/321 or A330/A340 aircraft. The FOT described a method by which 'pilots may practice aircraft handling in Alternate Law in a simulator and additionally perform an unreliable airspeed exercise at high altitude'.

The operators' A330 recurrent training session for the period October 2009 to March 2010 (session 2C) included an introduction to unreliable airspeed situations. Further training was included in the following session (April to September 2010). The operator first included unreliable airspeed situations in its A320 recurrent training sessions for the period May to September 2009, prior to the manufacturer's recommendation. The operator advised that unreliable airspeed training was included in its A330 and A320 recurrent training programs in response to the A330 in-flight upset event on 7 October 2008 involving an associated operator.[25] The operator also advised that its recurrent training programs were more extensive than the manufacturer-recommended programs, and included Australian regulatory requirements and internal training needs identified by a variety of mechanisms.

Other Australian operators

An associated Australian A330 operator (Qantas) advised that its A330 endorsement training was based on the manufacturer-recommended program and included unreliable airspeed training. Unreliable airspeed training was introduced into its recurrent training program on 19 June 2009, following the manufacturer's recommendation. In addition, every cyclic training session included testing on memory items, and every year one cyclic exercise included training in flight on standby instruments.

At the time of the occurrence, there were 23 A330 aircraft registered in Australia. All but one of those aircraft were operated by the two associated operators. The other aircraft was registered in Australia in June 2009 and the operator of that aircraft advised that its flight crew obtained their A330 endorsements from other operators, and that its recurrent training program was updated in response to the aircraft manufacturer's recommendation.

[25] As discussed later in the report, the in-flight upset event on 7 October 2008 was not the same type of event as the unreliable airspeed event involving EBA.

Guidance material

The aircraft manufacturer provided an FCTM to supplement the FCOM and provide pilots with practical information on how to operate the aircraft. The operator's A330 FCTM was based on the manufacturer's manual and contained a section on the unreliable airspeed / ADR check procedure. The material reviewed different types of unreliable airspeed scenarios and their potential effects, and provided a detailed explanation of the procedure itself. The material was first introduced in the manufacturer's FCTM in July 2004.

The aircraft manufacturer has also regularly published articles on unreliable airspeed procedures in its flight safety magazine (*Safety First*).

Personnel information

The captain had 18,722 total hours experience, including 2,123 hours on the A330. He also had 1,183 hours experience on A320 aircraft and had flown other air transport aircraft types. Prior to the occurrence, he could not recall having experienced an unreliable airspeed event. He also could not recall receiving training for an unreliable airspeed event in the simulator. He had not completed the recurrent training session 2C at the time of the event.

The first officer for the flight was also a qualified captain, but operating as a first officer on the flight due to a shortage of available first officers. He had 16,400 hours total experience, including 1,800 hours on the A330. He also had 2,400 hours experience on A320 aircraft and had flown other air transport aircraft types. Prior to the occurrence, he could not recall having experienced an unreliable airspeed event. He recalled that he received unreliable airspeed training as part of his A330 endorsement at the aircraft manufacturer's facilities, but could not recall receiving any recurrent training on the topic. He had not completed the recurrent training session 2C at the time of the event.

Both pilots had valid medical certificates, and flight and duty times in recent days were within acceptable levels.

Previous unreliable airspeed occurrences

Unreliable airspeed events can occur on any aircraft type, and due to a range of factors. Potential factors include pitot probes being partially or totally obstructed by water, ice, ashes or insect nests[26], or technical failures of probes or related components.[27] The present report is primarily concerned with airspeed events occurring at cruise levels and not associated with any technical faults of relevant components.

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26 For an example of pitot blockages by insect nests, see ATSB aviation occurrence report 200601453 (Rejected takeoff, Brisbane Airport, Qld, 19 March 2006, VH-QPB, Airbus A330-303) available at www.atsb.gov.au. Such events will become apparent during takeoff.

27 For an example of a failure of probe heating systems, see ATSB aviation occurrence investigation 200605307 (Erratic Airspeed Indications, 241 km NNE Perth Airport, 7 September 2006, VH-NXI, Boeing 717-200) available at www.atsb.gov.au.

It is important to note that the A330 unreliable airspeed occurrence on 28 October 2009 involving EBA was not the same type of event as the A330 in-flight upset events near Learmonth, Western Australia on 7 October 2008 involving VH-QPA (QPA). The two occurrences involved very different sequences of events and fault messages and, in the case of the QPA occurrence, the in-flight upsets were associated with erroneous angle of attack information rather than airspeed information.[28]

EBA, 15 March 2009

The operator and its associated Australian operator had 22 A330 aircraft in operation at the time of the 28 October 2009 occurrence. A review was conducted of the ATSB's occurrence database and those operators' maintenance records for any similar events on A330 aircraft. Only one previous event was identified.[29] The event involved the same aircraft as involved in the 28 October 2009 event (EBA) and occurred on 15 March 2009, during a scheduled passenger transport service operated as Jetstar flight 20 from Kansai International Airport, Japan to Coolangatta, Australia.

After the March 2009 event, the flight crew submitted a technical log entry that stated that the captain's airspeed 'disappeared', autopilot 1 disconnected and there were numerous maintenance system messages. It also stated that the event occurred when the aircraft was in cloud at high altitude (FL 390 or 39,000 ft), and that ice, turbulence and static (St Elmo's fire) were present. The crew noted that there was also a change in SAT from 'ISA + 4 to ISA + 23' degrees, which equated to an increase from about -52 °C to -33 °C.[30]

The PFR from the 15 March 2009 flight recorded that the event occurred at 1650 UTC. The cockpit effect messages were similar to the 28 October 2009 flight. However, there were no messages reporting that the flight directors had disconnected, and no NAV ADR DISAGREE or F/CTL RUD TRV LIM FAULT messages.

The 15 March 2009 occurrence was not investigated at the time. Following the 28 October 2009 occurrence, attempts were made to obtain additional information on the March 2009 occurrence. Although no FDR or DAR data was available for that flight, BITE data was able to be obtained from the EFCS and ADIRU 1 (which was replaced shortly after the March occurrence).

The PFR contained a maintenance fault message for ADIRU 1. The BITE data from ADIRU 1 indicated that it had the same fault messages as had occurred for ADIRU 1 on the 28 October 2009 flight, indicating that there were problems with the incoming airspeed information but not indicating any problems with the ADIRU itself. BITE data from the EFCS included a message reporting that a speed decrease of more than 30 kts in 1 second was detected on at least two airspeeds.

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28 For further information, see the available reports on ATSB aviation occurrence investigation AO-2008-070 (In-flight upset, 154 km west of Learmonth, Western Australia, 7 October 2008, VH-QPA, Airbus A330-303).

29 The operator of the other A330 in Australia advised that it had no reports of an unreliable airspeed indication event.

30 The international standard atmosphere (ISA) temperature at 39,000 ft is -56.5 °C.

Following the 28 October 2009 occurrence, the crew of the 15 March 2009 event were contacted to obtain additional information. They reported that, at the time of the event, the captain was on a rest break and the second officer was in the left seat. Tropical weather with thunderstorms was present at the time. The crew had been diverting around the worst of the weather, and were crossing between cells when the event occurred. St Elmo's fire was present at a moderate to high level.

The crew recalled that the captain's airspeed quickly went to zero, the autopilot disconnected and various other messages were presented on the ECAM. The event was over very quickly and there was no ongoing disagreement between the three airspeeds. The crew re-engaged autopilot 1 and autothrust without any further problems. The ALTN LAW message did not remain on, indicating that the flight control system reverted back to normal law following the event.

Analysis of recorded position reporting data indicated that the location of the 15 March 2009 event was 1,050 km north of Port Moresby (see Figure 1). An MTSAT image taken at 1630 that day showed that the aircraft's position was located within or under a large defined cluster of cumulonimbus clouds at that time. The radiative cloud top temperature at 1630 was -71.8 °C, which corresponded to cloud tops of over 47,500 ft. The most intense section of the cluster was located south to south-west of the event location.

Other unreliable airspeed events on A330/A340 aircraft

On 8 August 2001, the French Direction Generale de L'Aviation Civile (DGAC) issued Airworthiness Directives (ADs) 2001-353 for A340 aircraft and 2001-354 for A330 aircraft. The ADs required the replacement of Rosemount pitot probes model 0851GR with either BF Goodrich probes 0851HL or Sextant probes C16195AA.[31] The reason provided was:

> Operators have reported loss or fluctuation of airspeed when flying through extreme meteorological conditions.
>
> Further to an investigation, the presence of ice crystals and/or water exceeding the current limits of the initial specification of ROSEMOUNT Pitot probes P/N 0851GR is considered as the most probable cause of these airspeed discrepancies.

The Goodrich probes 0851HL were certified in November 1996. The probe manufacturer has stated that this model of probes had improved performance capabilities relative to the 0851GR model by 'increasing the power density in the tip region by 35% over the existing probe, and incorporating the high power density in the drain hole region to ensure proper drainage during severe icing conditions'.

On 1 June 2009, an Airbus 330-200, operated as flight AF447, impacted the Atlantic Ocean on a flight from Rio de Janeiro, Brazil to Paris, France. An investigation by the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) is ongoing, and the reasons for the accident have not yet been determined.[32]

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31 The manufacturer of Rosemount and BF Goodrich probes later became known as 'Goodrich', and the manufacturer of Sextant probes later became known as 'Thales'.

32 The BEA has released two Interim Reports on the 1 June 2009 accident that are available at http://www.bea.aero/en/index.php.

A series of maintenance messages that were transmitted by AF447 prior to the accident showed inconsistencies between the aircraft's airspeeds and the associated consequences on other aircraft systems. These included the same PFR messages as occurred on the 28 October 2009 occurrence involving EBA (for example, AUTO FLT AP OFF, NAV ADR DISAGREE and F/CTL ALTN LAW), as well as additional messages (for example, flight control computer faults). The Air France aircraft was fitted with Thales probes model C16195AA.

On 31 August 2009, EASA issued AD 2009-0195.[33] The AD required as a precautionary measure that, for A330/A340 aircraft equipped with pitot probes manufactured by Thales, these probes be replaced with units manufactured by Goodrich. The reason provided was:

> Occurrences have been reported on A330/340 family aeroplanes of airspeed indication discrepancies while flying at high altitudes in inclement weather conditions. Investigation results indicate that A330/A340 aeroplanes equipped with Thales Avionics pitot probes appear to have a greater susceptibility to adverse environmental conditions than aeroplanes equipped with Goodrich pitot probes.
>
> A new Thales Pitot probe P/N C16195BA has been designed which improves A320 aeroplane airspeed indication behaviour in heavy rain conditions. This same pitot probe standard has been made available as optional installation on A330/A340 aeroplanes, and although this has shown an improvement over the previous P/N C16195AA standard, it has not yet demonstrated the same level of robustness to withstand high-altitude ice crystals as the Goodrich P/N 0851HL probe. At this time, no other pitot probes are approved for installation on the A330/A340 family of aeroplanes.
>
> Airspeed discrepancies may lead in particular to disconnection of the autopilot and/or auto-thrust functions, and reversion to Flight Control Alternate law. Depending on the prevailing aeroplane altitude and weather environment, this condition could result in increased difficulty for the crew to control the aeroplane.

As part of the investigation into the AF447 accident, the BEA and aircraft manufacturer reviewed previous occurrences involving airspeed disagreement on A330/A340 aircraft. Appendix 7 of BEA's second Interim Report contained details of 36 occurrences between the period 12 November 2003 and 7 August 2009 that the aircraft manufacturer concluded were attributable to the blocking of at least two pitot probes by ice.[34] Of those 36 events:

- 27 events involved aircraft fitted with Thales model C16195AA pitot probes (certified April 1998) and three events involved aircraft fitted with Thales model C16195BA pitot probes (certified April 2007)
- two events involved aircraft fitted with Goodrich 0851HL probes (including the EBA event on 15 March 2009)[35]
- the type of pitot probe was not known for the other four events.

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[33] On 2 September 2009, CASA issued a corresponding AD (AD/A330/108).

[34] In the list of 36 events, there were five aircraft associated with multiple events.

[35] Based on the available information, the aircraft manufacturer has also concluded that the most probable explanation for the occurrence involving EBA on 28 October 2009 was at least two pitot probes partially and temporarily blocked by ice crystals.

The aircraft manufacturer advised that the majority of the worldwide A330/A340 fleet as at 1 June 2009 had the Goodrich 0851HL probes fitted. All of the two associated Australian operators' 22 A330s were fitted with Goodrich 0851HL pitot probes throughout their operational service history.[36]

In its second Interim Report into the AF447 accident, the BEA also reviewed 13 of the unreliable airspeed occurrences where there were crew reports, flight recorder data and a PFR available. Some key aspects of these 13 flights were:

- All flights were between FL 340 and FL 390.
- The crews all reported not observing any significant radar echoes on the chosen flight path but that they identified active zones lower or nearby. All the events occurred in instrument meteorological conditions (IMC). Only three crews reported having heard or observed what they identified as ice or rain.
- Recordings of SAT or TAT generally showed increases of 10 to 20 °C during the event.
- In all of the cases, turbulence was recorded and reported. The levels were reported to vary from slight to strong. In nine of the cases, a stall warning occurred.[37]
- The maximum continuous duration of invalid recorded speeds was 3 minutes 20 seconds. BEA and the aircraft manufacturer have advised the ATSB that the duration of the EBA event on 28 October 2009 was brief compared to most of the other events where recorded data was available.

The BEA advised that St Elmo's fire was sometimes but not always reported by the crews of aircraft that experienced an unreliable airspeed indication event. The pitot probe manufacturer also advised that the occurrence of St Elmo's fire would not affect the performance of an aircraft's pitot probes.

In summary, the environmental circumstances encountered by EBA on 28 October 2009 were similar to those of previous occurrences. However, the 28 October 2009 occurrence appeared to be less significant than many others in terms of its duration, and it did not involve stall warnings.

Unreliable airspeed events on A320 aircraft

The A320 family of aircraft has a similar systems architecture to the A330/A340 and uses the same types of pitot probes. The aircraft manufacturer advised that unreliable airspeed occurrences do occur on the A320 family in the takeoff, climb, descent and approach phases, but that the rate of occurrence during the cruise phase was lower than for the A330/A340 fleet.

A review of the ATSB database identified that there had been three unreliable airspeed events at high altitude on the A320/A321 fleet in recent years that had been reported to the ATSB. All three occurred on aircraft fitted with Thales probes and involved the same operator as operated EBA. A review of the operator's

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36 The other A330 aircraft registered in Australia (June 2009) originally had Thales BA probes fitted. These were replaced in accordance with the relevant CASA airworthiness directive.

37 Turbulence can cause brief angle of attack fluctuations that can generate spurious stall warnings. In normal law, spurious warnings are eliminated by setting a high angle of attack threshold to trigger a stall warning. In alternate law this high warning threshold is removed.

maintenance records and occurrence reports identified no additional events. Details of the three A320 events are at Appendix A.

Design and certification issues

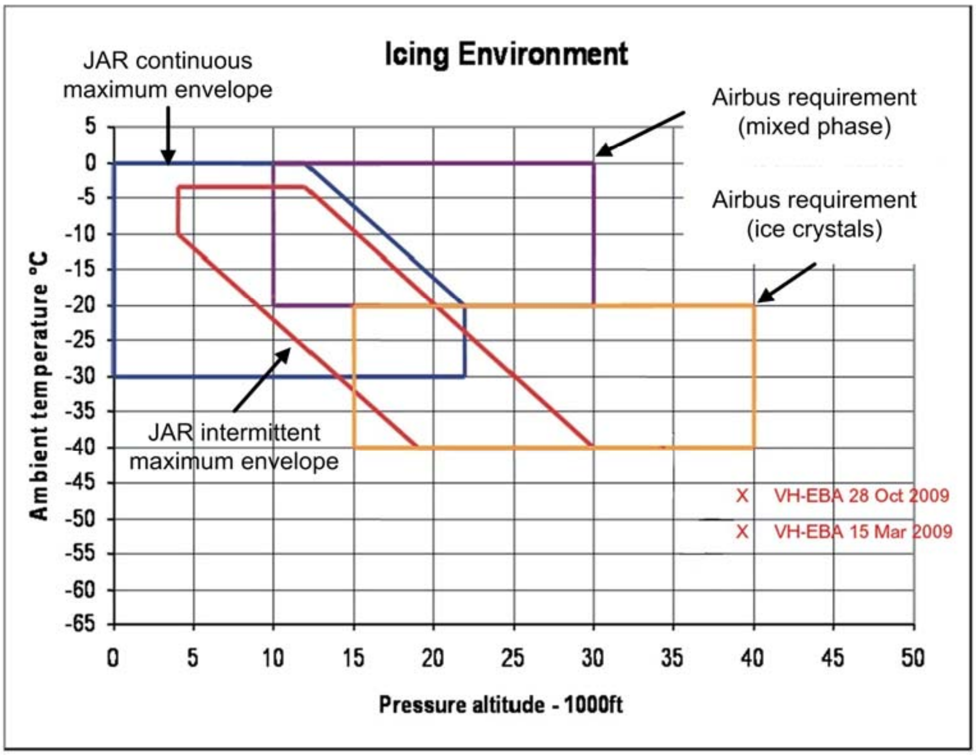
Pitot probe design specifications

The European Joint Aviation Requirement (JAR) 25.1409 and Appendix C to JAR 25 outlined the certification standard for validating the anti-icing protection systems on aircraft in super-cooled water icing conditions. The standard included specified envelopes of pressure altitude and ambient temperature for continuous maximum and intermittent maximum icing conditions.

In order to cover all of the icing conditions specified in Appendix C of JAR 25, the aircraft manufacturer developed a ten-point test table with different SATs, speeds, TATs, water concentrations per cubic metre of air, mean diameters of the water droplets, exposure time, pitot heating electrical power supply and the probe's local angles of attack in order to cover the aircraft's flight envelope. The manufacturer also specified 16 additional test points to meet additional criteria, thus covering a wider envelope than that defined by JAR 25.

The JAR and the aircraft manufacturer's icing envelopes are plotted on Figure 5. In Appendix 4 of its second Interim Factual report on the AF447 accident, the BEA plotted the environmental conditions associated with 13 unreliable airspeed events for which detailed information was available. All of the events were outside the JAR envelopes. In addition, 12 events were outside the manufacturer's envelopes, with the other being just inside the lower temperate boundary for ice crystals. Figure 5 shows that the EBA occurrence on 28 October 2009 also occurred in conditions outside the JAR and manufacturer's envelopes. Based on the crew report of the SAT at the time, the 15 March 2009 event also occurred in conditions outside the envelopes.

Figure 5: Icing envelopes



Based on its review of the topic, the BEA's second Interim Factual report on the AF447 accident concluded (section 4.2):

> In fact, the certification criteria are not representative of the conditions that are really encountered at high altitude, for example with regard to temperatures. In addition, it appears that some elements, such as the size of the ice crystals within cloud masses, are little known and that it is consequently difficult to evaluate the effect that they may have on some equipment, in particular the Pitot probes. In this context, the tests aimed at the validation of this equipment do not appear to be well-adapted to flights at high altitude.

Consequently, the BEA made recommendations for the European Aviation Safety Agency (EASA) to undertake further research into the composition of cloud masses at high altitude, as well as to review the certification criteria for pitot probes in icing environments (see the *SAFETY ACTION*).

Failure condition classifications

During the certification of A330/A340 aircraft in the early 1990s, JAR 25.1309 outlined the requirements for the type certification of the associated equipment and systems. Advisory Circular Joint (ACJ) No. 1 to 25.1309 outlined further guidance to meet the JAR. As part of that requirement, the aircraft manufacturer needed to identify potential failure conditions associated with each relevant system, and to assess their effect on safety (minor, major, hazardous or catastrophic).

During its system safety assessment process for the A330/A340, the aircraft manufacturer classified the effect of the potential failure condition associated with inconsistencies in measured airspeeds as ‘major’. This classification was subsequently confirmed by the aircraft manufacturer and EASA in 2009.

A ‘major’ failure condition was defined in the ACJ as one that resulted in a ‘significant reduction in safety margins’, or a ‘reduction in the ability of the flight crew to cope with adverse operating conditions as a result of increase in workload or as a result of conditions impairing their efficiency’. In contrast, ‘hazardous’ was defined as ‘large reduction in safety margins’ and ‘catastrophic’ as ‘loss of the aircraft and/or fatalities’.

According to ACJ No. 1, failure conditions classified as ‘major’ should not occur at a likelihood greater than ‘remote’. The term ‘remote’ was defined as meaning it was unlikely to occur to each aircraft during its total life, but may occur several times when considering the total operational life of all aircraft of the same type. It was described as being equivalent to a likelihood of 10^{-5} to 10^{-7} per flight hour. The operator of EBA and the associated Australian operator had over 400,000 hours of A330 operation in the period 2003 to 2009. The rate of unreliable airspeed events during cruise was therefore less than $5x10^{-6}$ (and within the 10^{-5} to 10^{-7} per flight hour range). If the large number of other operators using the same pitot probes is considered, the rate of such events was substantially lower across the world fleet.

ANALYSIS

Introduction

At 1537 on 28 October 2009, there were disagreements in the three sources of airspeed information on Airbus A330-202 aircraft, registered VH-EBA (EBA). This was the second event of this type involving the same aircraft, and one of only three events known to have occurred on Airbus A330/A340 aircraft fitted with Goodrich 0851HL pitot probes.

The consequences of the airspeed disagreement event in the 28 October 2009 occurrence were not hazardous. There was a brief loss of availability of the autopilot and a number of other flight guidance functions, and the flight control system reverted to alternate law for the remainder of the flight. There was no effect on the aircraft's flight path.

Although this airspeed disagreement event was relatively benign in nature, airspeed is a critically important parameter for aircraft control. Accordingly, a safety investigation was initiated to examine the reasons for this event, consider why two events had occurred on the same aircraft, and consider the suitability of the risk controls in place to minimise the frequency, duration and adverse consequences of such events for Australian A330 operators. Relevant risk controls included the design and reliability of relevant aircraft systems, flight crew procedures, and associated flight crew training.

Reasons for the airspeed disagreements

The flight recorder data showed that there was a significant but brief (5-second) decrease in the airspeed on the captain's airspeed system. The first officer's and standby airspeed systems were not recorded. However, the aircraft's flight control system reverted to alternate law for the remainder of the flight, indicating that there were significant disagreements between the three airspeed sources over a period of at least 10 seconds. Built-in test equipment (BITE) data also showed that there were temporary problems with the airspeed information provided by the standby system at about the time of the reduction in the captain's airspeed, and again about 1 minute later.

The drop in the captain's airspeed was consistent with the pitot probe being obstructed for about 5 seconds. The drops in the standby airspeed were also consistent with the standby probe being temporarily obstructed. Although both the captain's and standby airspeed indications were affected at about the same time, they were not affected to the same degree at exactly the same time.

In addition to temporary problems with at least two airspeed sources, recorded data showed that there were temporary problems with at least one of the total air temperature (TAT) sources during the same period. The changes in temperature were consistent with the captain's TAT probe being obstructed on two occasions.

Given that there were temporary obstructions of at least three of the aircraft's probes during the same period, the most likely explanation is an environmental factor. The observed weather conditions were consistent with previous similar events on A330/A340 aircraft where obstruction of the pitot tubes by ice crystals at high altitudes was considered the most likely explanation. The observed conditions were also outside of the design specifications (temperature and altitude) of the certifying authority and the aircraft manufacturer for the pitot probes in icing environments.

The same aircraft (EBA) had a similar occurrence on 15 March 2009, although the resulting maintenance messages suggested that event was less significant. The reported weather conditions for that event were also consistent with those of previous events. Although having two events on the same aircraft may suggest a specific problem associated with that aircraft or its components, tests and examinations identified no such problem.

In summary, it is reasonable to conclude that the unreliable airspeed occurrences involving EBA on 28 October 2009 and 15 March 2009 resulted from at least two of the aircraft's pitot probes being temporarily obstructed by ice crystals.

Pitot probe design requirements

Large airline aircraft, such as the A330/A340, do not have any flight crew operating manual restrictions imposed on operations in severe icing conditions. Although the aircraft has three independent speed-sensing systems, environmental factors such as icing have the potential to remove this redundancy and give simultaneous failures. The design of the pitot probes has been shown to be insufficient to prevent them being obstructed with ice in some specific conditions that aircraft encounter.

Including the 28 October 2009 occurrence and the AF447 accident on 1 June 2009, there have been at least 38 unreliable airspeed events at high altitudes or in reported icing conditions on A330/A340 aircraft between November 2003 and October 2009. However, the occurrence rate for aircraft fitted with Goodrich 0851HL probes is much lower than for aircraft fitted with other pitot probes previously approved for the A330/A340. There have been only three reported occurrences involving Goodrich model 0851HL probes, including the 15 March 2009 and 28 October 2009 occurrences involving EBA. In addition, the two occurrences involving EBA were relatively brief in duration and there was no effect on the aircraft's flight path in either case.

As part of its investigation into the Air France A330-200 accident on 1 June 2009, the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) is conducting a comprehensive examination of pitot probe certification and related issues. There was little safety benefit in the ATSB investigation repeating the safety action that has already been directed to the European Aviation Safety Agency by the BEA.

Flight crew procedures and training

Even though the occurrence rate for the 0851HL probes is much lower than for other models, unreliable airspeed events can still occur in some environmental conditions. There were procedures in place to deal with such situations, and guidance material provided in the operator's A330 *Flight Crew Training Manual*. During the 28 October 2009 occurrence, and the previous occurrence on 15 March 2009, the crews followed the required procedures. However, both events were relatively benign in nature, and did not require the use of all aspects of the unreliable airspeed / ADR (air data reference) check procedure. Had the airspeed disagreements persisted for a much longer duration, then the situation could have posed a more significant challenge for the crews to manage.

Many of the operator’s A330 pilots had not received specific training in unreliable airspeed situations prior to the 28 October 2009 occurrence. Some of the operator’s pilots had received such training during their A330 endorsements (such as the first officer on the 28 October 2009 occurrence flight), but most of the pilots had transferred from the A320 and had not received such training either during their A320 endorsement or during the cross crew qualification training.

The absence of unreliable airspeed training for many of the operator’s A330 pilots prior to October 2009 was not necessarily a significant safety issue given the low likelihood and apparently benign nature of such events for aircraft equipped with the Goodrich probes. In addition, the operator was actively addressing the situation, and had started including unreliable airspeed situations into its A330 recurrent training in October 2009 (and into its A320 recurrent training program in May 2009).

Nevertheless, there was a residual safety issue associated with the third-party training provider’s A320 endorsement training program. The aircraft manufacturer is a critically important source of information about the content to include in a training program, based on its collection of information about in-service experience and occurrences from operators. However, the training provider did not have a current version of the aircraft manufacturer’s recommended training program and therefore could not utilise this important source of information when revising or maintaining its syllabus.

Although the training provider could receive requests from operators to make changes to its training program, this process did not necessarily provide a high level of assurance that changes would be made in line with the manufacturer’s recommendations in a timely manner. The aircraft manufacturer had included unreliable airspeed training in its recommended training program since 2003, but the training provider was not aware of this change and had not included this topic in its training program prior to the 28 October 2009 occurrence.

The Civil Aviation Safety Authority had an expectation that the operator would provide the training provider with updated materials from the aircraft manufacturer. However, the operator could not provide the training provider with the aircraft manufacturer’s materials due to copyright restrictions. This situation appeared to be another example of unclear responsibilities between operators and third-party training providers identified in previous Australian Transport Safety Bureau investigations, and one that required all the involved parties to take action to ensure that future endorsement training was consistent with the latest advice from the aircraft manufacturer.

FINDINGS

Context

On a flight from Narita, Japan to Coolangatta, Australia on 28 October 2009, an Airbus A330 aircraft (VH-EBA) experienced an unreliable airspeed indication event that resulted in the disconnection of the autopilot and other flight guidance functions, a NAV ADR DISAGREE caution message, and the flight control system reverting to alternate law.

From the evidence available, the following findings are made with respect to the unreliable airspeed occurrence and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- At least two of the aircraft’s pitot probes were temporarily obstructed, probably due to ice crystals.

Other safety factors

- Although the pitot probes fitted to A330/A340 aircraft met relevant design specifications, those specifications were not sufficient to prevent the probes from being obstructed with ice during some types of environmental conditions that the aircraft could encounter. *[Significant safety issue]*
- As of 28 October 2009, many of the operator’s A330 flight crew had not received unreliable airspeed training, either during endorsement training or recurrent training. The operator started introducing such training in its recurrent training program in early October 2009. *[Minor safety issue]*
- When revising or maintaining its A320 endorsement training program, the third-party training provider did not use or have access to current versions of the aircraft manufacturer’s recommended training program. *[Minor safety issue]*

Other key findings

- There was no effect on the aircraft’s flight path due to the airspeed disagreement and consequential brief unavailability of flight guidance functions.
- The aircraft was fitted with Goodrich model 0851HL pitot probes, which have been associated with a much lower rate of pitot probe obstruction due to icing compared to other pitot probe models previously approved for the A330/A340.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety 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 responsible organisations for the safety issues identified during this investigation were given 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.

Certification requirements for icing conditions

Significant safety issue

Although the pitot probes fitted to A330/A340 aircraft met relevant design specifications, those specifications were not sufficient to prevent the probes from being obstructed with ice during some types of environmental conditions that the aircraft could encounter.

Action taken by the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile

In its second Interim Report on the investigation into the Air France A330-200 accident on 1 June 2009, the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA) issued the following recommendations to the European Aviation Safety Agency (EASA):

> 1. undertake studies to determine with appropriate precision the composition of cloud masses at high altitude,
>
> and
>
> 2. in coordination with the other regulatory authorities, based on the results obtained, modify the certification criteria.

ATSB assessment of action

Given the comprehensive scope of the BEA investigation, there is no need for the ATSB to make any additional recommendations regarding this safety issue.

Training for unreliable airspeed situations

Minor safety issue

As of 28 October 2009, many of the operator's A330 flight crew had not received unreliable airspeed training, either during endorsement training or recurrent training. The operator started introducing such training in its recurrent training program in early October 2009.

Action taken by Jetstar

The operator included an introduction to unreliable airspeed situations in its A330 recurrent (cyclic) training session for the period October 2009 to March 2010. Further training is being included in the following cyclic session (April to September 2010).

Action taken by other Australian A330 operators

The associated Australian A330 operator (Qantas) advised that its A330 cyclic training session from 19 June 2009 to January 2010 included discussion items and a simulator exercise applying the unreliable airspeed / ADR check procedure. The operator of the only other A330 aircraft registered in Australia also advised that it had started including unreliable airspeed training in its training programs.

ATSB assessment of action by the operators

The ATSB is satisfied that that the action by the Australian operators adequately addresses this safety issue.

A320 endorsement training program

Minor safety issue

When revising or maintaining its A320 endorsement training program, the third-party training provider did not use or have access to current versions of the aircraft manufacturer's recommended training program.

Action taken by various organisations

In July 2010, the training provider (Boeing Training and Flight Services) received approval from the Civil Aviation Safety Authority (CASA) for a revised A320 endorsement training program that included unreliable airspeed training.

The operator (Jetstar) advised that it was conducting regular training gap analysis of third-party training programs versus aircraft manufacturer recommendations.

The operator and the training provider also reported that they were examining options to enable the training provider to directly access the aircraft manufacturer's recommended training program.

CASA advised that new regulations applying to third-party training parties were expected to be introduced in 2011 with an effective date of 2012, and that these rules would more clearly specify the responsibilities of the training providers. It also advised that it was reviewing its processes for providing approvals for training providers' training programs.

ATSB assessment of action

The ATSB is satisfied that that the action taken to date, and action proposed to be taken, by the various organisations will, when completed, adequately address this safety issue.

APPENDIX A: A320 UNRELIABLE AIRSPEED EVENTS

The following three A320 unreliable airspeed events at high altitude (and that were not associated with technical failures) occurred in Australia during the period 2008 to 2010. No other similar events were identified for the period 2000-2007.

VH-JQL, 5 February 2008

On 5 February 2008, an Airbus A320-232 aircraft, registered VH-JQL and operated by Jetstar, experienced an unreliable airspeed event on a flight from Brisbane to Proserpine, Queensland. The crew reported that the event occurred when approaching top of climb in cloud and rain and after they had diverted around significant weather. The captain's airspeed indication 'disappeared' followed soon after by disconnection of the autopilot and several electronic centralised aircraft monitor (ECAM) messages. These included NAV ADR DISAGREE and F/CTL ALTN LAW. The crew responded to a THRUST LOCK message. Shortly afterwards, the captain's airspeed returned to normal and the aircraft levelled off at FL 360. Given that the airspeeds were then in agreement, the crew did not proceed further with the ADR CHECK procedure. After discussing the situation with the operator's operations centre, the crew elected to return to Brisbane.

The crew reported that the environmental conditions were conducive for icing, and that the captain's airspeed was affected for about 2 minutes. Subsequent inspections identified no problems with any components. The aircraft was fitted with Thales C16195AA pitot probes at the time (replaced soon after by C16195BA probes).[38]

VH-JQG, 16 February 2010

On 16 February 2010, an Airbus A320-232 aircraft, registered VH-JQG and operated by Jetstar, experienced an unreliable airspeed event in cruise at FL 350 on a flight from Cairns to Brisbane, Queensland. About 10 minutes before the event, the captain reported that some ice crystal formation was observed around the wipers, resembling a fine white dust. Just prior to the event, the crew noticed the static air temperature (SAT) fluctuating, the precipitation had increased and there was light turbulence. The aircraft's weather radar showed light intensity returns and a cell that was located 40 NM (74 km) west of the aircraft's track.

About halfway into the flight, at 0613 UTC (1613 local time), a NAV ADR DISAGREE ECAM caution occurred, the autopilot and autothrust disconnected and the flight controls reverted to alternate law. The crew reported that level of turbulence also started to increase.

The crew selected both flight directors OFF and manual thrust was engaged. Air traffic control asked the crew to confirm their altitude, and they requested descent to FL 330. A manually flown descent to FL 330 was initiated and ECAM actions completed. No discrepancy in airspeeds or other parameters was noted at that time.

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38 The EASA AD 2009-0195 for A330/A340 aircraft noted that the C16195BA 'improves A320 aeroplane airspeed indication behaviour in heavy rain conditions' compared to C16195AA probes.

A PAN[39] was declared, the autopilot and autothrust were restored, and the landing at Brisbane was uneventful. There were no injuries reported.

Analysis of flight data recorder and system built-in test equipment data showed that it was likely that the first officer's pitot, the standby pitot and the captain's total air temperature probes had been partially and temporarily obstructed. The airspeed discrepancies lasted over a period of about 2 minutes. Subsequent inspections identified no problems with any components, although one of the pitot probes made a different noise when air was passed through it when compared to the other probes. The aircraft was fitted with Thales C16195BA probes at the time of the event and these were replaced by Goodrich 0851HL probes.[40]

The operator included unreliable airspeed situations in its cyclic training sessions on the A320 fleet in May to September 2009 and May to September 2010.

VH-JQX, 20 September 2010

On 20 March 2010, an Airbus A320-232 aircraft, registered VH-JQX and operated by Jetstar, was conducting a scheduled passenger flight from Brisbane to Mackay, Queensland. On decent into Mackay, the crew received multiple ECAM messages. The aircraft was in instrument meteorological conditions at the time.

The aircraft's FDR and QAR data showed there was incorrect data recorded temporarily for the captain's airspeed, the copilot's airspeed, and the captain's TAT probe. Further details of this event are provided in the ATSB Aviation Level 5 Investigation AO-2010-070, available at www.atsb.gov.au .

Additional information

The operator advised that, as of the end of November 2010, all of its A320 aircraft and most of its A321 aircraft were fitted with Goodrich 0851HL probes, and by the end of December 2010 the remainder of its A321 aircraft would be fitted with the Goodrich probes.

39 A PAN transmission is made in the case of an urgency condition which concerns the safety of an aircraft or its occupants, but where the flight crew does not require immediate assistance.

40 Although EASA had issued an airworthiness directive on 31 August 2009 to replace Thales pitot probes on A330/A340 aircraft, there was no such requirement to replace probes on A320 aircraft.

APPENDIX B: SOURCES AND SUBMISSIONS

Sources of information

The sources of information during the investigation included:

- the flight crew of VH-EBA (for both occurrences)
- the aircraft operator and an associated A330 operator
- the aircraft manufacturer and relevant component manufacturers
- the French Bureau d'Enquêtes et d'Analyses pour la sécurité de l'aviation civile (BEA)
- recorded flight and other data.

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 of both A330 occurrences, the aircraft and associated aircraft operators, the aircraft and pitot probe manufacturers, the third-party training provider, Civil Aviation Safety Authority, the BEA and the US National Transportation Safety Board.

Submissions were received from the flight crew, the operator and the aircraft manufacturer. Those submissions were reviewed and, where necessary, the text of the report was amended accordingly.

Unreliable airspeed indication
710 km south of Guam, 28 October 2009
VH-EBA, Airbus A330-202