



Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY INVESTIGATION REPORT

Aviation Occurrence Investigation – 200604439

Final

Stall warning device event – Alice Springs, NT

2 August 2006

VH-NXE

Boeing Company 717-200



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Released in accordance with section 25 of the *Transport Safety Investigation Act 2003*

Published by: Australian Transport Safety Bureau
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ISBN and formal report title: see 'Document retrieval information' on page iii.

DOCUMENT RETRIEVAL INFORMATION

Report No.	Publication date	No. of pages	ISBN
200604436	30 January 2008	19	978-1-921165-76-4

Publication title

Stall warning device event - Alice Springs, NT - 2 August 2006 - VH-NXE, Boeing Company 717-200

Prepared by

Australian Transport Safety Bureau
PO Box 967, Civic Square ACT 2608 Australia
www.atsb.gov.au

Reference No.

Jan2008/Infrastructure 8013

Acknowledgements

Figure 1. Boeing Commercial Aviation Services

Abstract

At 0938 Central Standard Time on 2 August 2006, a Boeing Company 717-200 aircraft, registered VH-NXE, took off from Alice Springs Airport, NT, on a scheduled flight to Perth, WA. The applicable aircraft take-off settings and techniques were applied by the flight crew for the takeoff. The recorded data showed that, 4 seconds after lift off, when about 31 ft above the runway, the aircraft's stall warning system activated for 4 seconds, and that the aircraft did not approach an aerodynamic stall condition at any time during the stick shaker activation. In response to the activation of the stick shaker, the flight crew increased engine thrust and reduced the aircraft's pitch attitude.

It is almost certain that an incorrect left wing slat sensor signal was received by the proximity sensing electronics unit (PSEU) from one of the two left wing slats proximity sensors. Consequently, the different slat position signals from the two sensors in the left wing resulted in the PSEU defaulting to the slats not-extended indication for the left wing. As a result of the different slat position signals sent by the proximity sensing electronics unit for the left wing (slats not-extended) and right wing (slats extended), the aircraft's flight control computers used the flaps-extended/slats-retracted stick shaker angle of attack schedule, leading to stick shaker activation and other stall indications.

Although no explanation could be found for the incorrect signal received by the PSEU from one of the two left wing slats proximity sensors, the aircraft manufacturer concluded that there did not appear to be a systemic problem in the worldwide 717 fleet.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal bureau within the Australian Government Department of Infrastructure, Transport, Regional Development and Local Government. ATSB investigations are independent of regulatory, operator or other external organisations.

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 enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, 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 proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

FACTUAL INFORMATION

Sequence of events

On 2 August 2006, a Boeing Company 717-200 (Boeing 717) aircraft, registered VH-NXE, took off from runway 30 at Alice Springs Airport, NT, on a scheduled flight to Perth, WA. There were two flight crew, four cabin crew and 63 passengers on board the aircraft. Shortly after lift off, when the aircraft was about 31 feet above the runway, the aircraft's stall warning system activated for a period of 4 seconds.

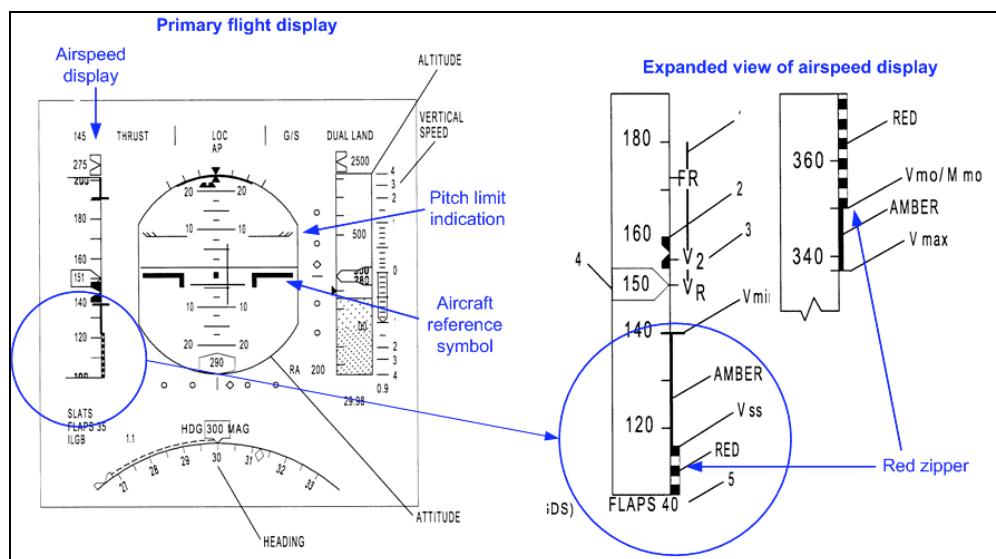
The copilot was the handling pilot for the takeoff. The flight crew reported that, as the non-handling pilot selected the landing gear lever to the retract position after lift off, they both noticed the red checked columns¹ ('red zippers') appear from the top and bottom of the airspeed display on the electronic primary flight display, and that the red zippers were converging. The aircraft pitch limit indicator² was also observed by the crew to be converging with the aircraft reference symbol on the primary flight display (Figure 1).

The handling pilot recalled confirming the aircraft's airspeed at that time as being 160 kts, that the flaps were extended, and that the aircraft was achieving an appropriate rate of climb. The flight crew reported that, as the pitch limit indicator 'touched' the aircraft reference symbol, it turned red and the aircraft's stick shaker³ activated.

The flight crew stated that, in response to the activation of the stick shaker, the handling pilot applied maximum engine thrust and maintained the existing aircraft attitude. The flight crew recalled that the pilot in command, who was concerned that stick pusher⁴ activation may occur, then applied forward pressure on the control column to reduce the aircraft's pitch attitude after the copilot increased the thrust. Shortly after its initial activation, the stick shaker ceased operating. The pilot in command reported that visual contact with the ground was maintained at all times during the event.

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- 1 The red checked columns, also referred to as 'red zippers', on the airspeed display provided an indication of the aircraft's current speed in relation to stick shaker speed (lower red column on the airspeed display). The top of the lower red column indicated the speed at which stick shaker activation would occur.
 - 2 The pitch limit indicator on the primary flight display indicated when the aircraft was near or in an aerodynamic stall condition. It was usually cyan in colour; however, upon reaching a stick shaker angle of attack condition, the indicator would change to red.
 - 3 The stick shaker was part of the aircraft's stall warning system, and indicated to the crew when the aircraft was approaching an aerodynamic stall by activating electrical motors that caused both pilots' control columns to vibrate rapidly.
 - 4 The stick pusher was a 'push' servo actuator that was part of the aircraft's stall warning system. The stick pusher moved the pilots' control columns forward to initiate a stall recovery manoeuvre if the aircraft was in an aerodynamic stall condition. The stick pusher only operated above 150 ft radio altitude.

Figure 1: Primary flight display showing airspeed tape with 'red zipper' warning indication⁵



Following the cessation of stick shaker operation, the crew observed that the CONFIG cue switch/light⁶ had illuminated on the rear pedestal between the two crew seats. The crew also observed three messages on the 'engine and alert display' screen on the centre instrument panel: PSEU FAIL⁷; WSHEAR DET FAIL; and STICK PUSHER FAIL (see the *Aircraft information* section below for explanations of those messages). The crew reported that those messages were displayed for about 1 to 2 minutes.

The crew maintained the aircraft in the existing configuration (landing gear retracted, and the wing flaps and leading edge slats extended), until the aircraft climbed clear of the surrounding terrain.

The crew contacted the operator's ground engineer at Alice Springs and provided information about the incident. In turn, the engineer contacted the operator's main maintenance base in Adelaide, SA, and discussed the occurrence and sought advice. That advice was then relayed back to the crew. When in receipt of all of the available information, and after discussion between both crew members and the ground engineer, the pilot in command elected to continue the flight to Perth.

Personnel information

Both pilots were endorsed on the Boeing 717 aircraft. The pilot in command had 546 hours on type, and the copilot had 614 hours on type.

⁵ Vss refers to stick shaker speed.

⁶ The CONFIG cue switch/light enabled the crew to select the aircraft configuration display on the system display screen, which was located on the centre instrument panel.

⁷ The crew reported observing the partial message 'PSEU [xxx]'. That message was most likely the PSEU FAIL advisory message, as that message resulted in the illumination of the CONFIG cue switch/light. Another message associated with the proximity sensing electronics unit was the PSEU FAULT status message, however, the CONFIG cue switch/light would not illuminate when that message is displayed.

Meteorological information

The pilot in command stated that the weather conditions for the takeoff were reported as CAVOK⁸, temperature 23° C, while the wind velocity was a steady west-north-westerly at approximately 10 kts.

The Bureau of Meteorology 1-minute weather observations at Alice Springs at 0938 were an average wind speed of 11 kts, gusting to 14 kts, from 320 degrees magnetic. The air temperature was 23.0° C and the QNH⁹ was 1017.6 hPa.

Flight data recorder information

The aircraft was equipped with a Honeywell Intl. Inc. solid state flight data recorder (FDR) and a quick access recorder. Information from the FDR and quick access recorder was downloaded by the aircraft operator and forwarded to the Australian Transport Safety Bureau (ATSB) for processing and analysis.

Occurrence takeoff

The FDR data revealed that the flaps/slats handle was positioned at 8 degrees about 5 minutes before the takeoff. The flaps and slats extended as commanded, but the FDR data recorded the flaps position as 9 degrees. Both wings' flaps were recorded as moving from 9 to 8 degrees during the take-off roll, although there was no associated movement of the flaps/slats handle recorded.

The aircraft was recorded as becoming airborne at 0937:56 Central Standard Time¹⁰ at 150 kts (Table 1). The stick shaker warning activated about 4 seconds after lift off, at which time the aircraft was travelling at 160 kts and was at about 31 ft above the runway. At that time, the left flaps indication returned to 9 degrees and, 1 second later¹¹, the left wing slats were recorded as being unlocked from the extended position.

The recorded data showed that, at 3 seconds after the activation of the stick shaker, the thrust levers were advanced. The stick shaker ceased 4 seconds after its onset, at which time the aircraft was travelling at 162 kts and was at about 168 ft above the runway.

8 CAVOK refers to the visibility, cloud and present weather being better than the following values or conditions: visibility 10 km or greater; no cloud below 5,000 ft, or the highest minimum sector altitude, whichever is greater; no cumulonimbus cloud; and no significant weather.

9 QNH is the barometric pressure setting that enables an altimeter to indicate aerodrome elevation; that is, the height above mean sea level.

10 The 24-hour clock is used in this report to describe the local time of day, Central Standard Time (CST), as particular events occurred. Central Standard Time was Coordinated Universal Time (UTC) + 9.5 hours.

11 It is possible that these stick shaker and slats retracting events were almost coincident and that the sampling and recording of each parameter, once per second, resulted in the presentation of the actions in subsequent seconds.

There was no change in the position of the flaps/slats handle during the takeoff. The left wing slats were recorded as having re-locked into the extended position 67 seconds after being recorded as unlocked.

While the left wing slats were recorded as unlocked from the extended position, the aircraft's recorded roll attitude did not significantly differ from other times during the takeoff. During that time, recorded aileron movements were minor.

The aircraft's pitch attitude was 4.5 degrees at lift off and increased to a maximum of 18.5 degrees 5 seconds later (1 second after the stick shaker activation). During that time, the average rate of rotation was 2.1 degrees per second from rotation¹² until reaching the maximum recorded pitch attitude. The pitch attitude of the aircraft then reduced as the crew applied forward pressure on the control column.

The FDR data revealed that forward pressure was initially applied to the control column 1 second before the onset of the stick shaker and that the column was then returned to about its original position. Another forward pressure was applied to the control column 4 seconds later, before it again returned to about the original position. The control column was moved forward a third time 2 seconds after the stick shaker ceased operating, and then remained at around the zero degree position.

The angle of attack¹³ increased during rotation from 4.3 degrees at lift off, to a maximum of 11.6 degrees 5 seconds later (1 second after the onset of the stick shaker), and then reduced (Table 1).

The horizontal stabiliser position was at a constant -2.7 degrees (aircraft nose up) throughout the take-off sequence.

A vertical acceleration of 1.2 g¹⁴ was recorded immediately before and during the stick shaker event, suggesting that there was no significant turbulence affecting the aircraft at that time.

The crew retracted the wing flaps 133 seconds after lift off, at which time the aircraft was at an altitude of 7,606 ft and travelling at 217 kts. The leading edge slats were retracted 55 seconds later, at 8,018 ft and 250 kts.

Previous takeoffs

The above data was compared with that recorded during the aircraft's previous take-off sequence. On that flight, the flight crew positioned the flaps/slats handle to 10 degrees for takeoff, and the sensors in the wing indicated that the flaps were at 10 degrees and that the slats were extended. When the aircraft became airborne, the data recorded that the right wing flaps momentarily indicated 9 degrees, before returning to 10 degrees. The recorded position of the slats did not change until the movement of the flaps/slats handle. There were no recorded stick shaker events.

12 Rotation refers to positive, nose-up rotation of the aircraft about its lateral (or pitch) axis immediately before becoming airborne.

13 The angle of attack is the angle formed between the relative airflow and the chord line of the wing.

14 Loading applied to a structure as a multiple of the normal acceleration due to Earth gravity.

Table 1: FDR data from rotation and during the initial climb¹⁵

Time (local)	Recorded event	Radio altitude (ft)	Air-speed (kts)	Pitch attitude (degrees)	Angle of attack (degrees)	Roll attitude (degrees)
0937:53	Left flaps 9 degrees; Right flaps 8 degrees	-	139	0.1	1.8	0.1
0937:54	Rotation commenced; Nose landing gear becomes airborne.	-	143	0.6	2.3	0.1
0937:55	Left flaps 8 degrees	-	147	1.8	2.8	-0.1
0937:56	Lift-off (main landing gear becomes airborne)	-	150	4.5	4.3	0
0937:57		0	152	8.1	7.6	-0.3
0937:58		4	153	11.9	10.4	-0.2
0937:59	Control column initially pushed forward;	14	154	14.3	11	0.5
0938:00	Stick shaker onset	31	160	16.4	11	-0.2
0938:01	Left slats retracting; Left flaps 9 degrees; Landing gear retracting ¹⁶	54	164	18.5	11.6	-0.6
0938:02		88	160	16.2	8.6	0.1
0938:03	Thrust lever angle increased; Control column pushed forward (2 nd time);	126	159	15.3	8	-1.7
0938:04	Stick shaker ceased; Engine N1 ¹⁷ increased from 89% to 90%	168	162	14.1	7.8	-2.3
0938:05	Engine EPR ¹⁸ increased from 1.40 to 1.42	204	164	10.2	5.4	-0.7
0938:06	Control column pushed forward (remaining in position); EPR increased to 1.43	234	164	11.3	6.5	-0.4
0938:07		260	165	12.3	7.8	0.4
0938:08		285	170	12.3	6.7	0

15 The radio altitude (height above the runway), pitch angle, and angle of attack data presented in Table 1 were measured from the left (pilot in command's side) of the aircraft.

16 Landing gear extended/retracting parameters were recorded every 4 seconds. Therefore, the landing gear may have been selected to the retracted position up to 3 seconds earlier.

17 N1 refers to the speed of the first stage fan or low speed compressor in a turbine engine.

18 EPR refers to engine pressure ratio, which is an indication of the thrust being developed by a turbine engine. It is the ratio of turbine discharge pressure divided by compressor inlet pressure.

Aircraft information

Stall warning system

The aircraft's stall warning system was designed to provide a warning to the flight crew when the aircraft was approaching, or was in, an aerodynamic stall condition.¹⁹ The system relied on information from the aircraft's two flight control computers, which independently computed the aircraft's proximity to stall conditions. That was achieved by the monitoring of the aircraft's angle of attack, the position of the horizontal stabiliser, and the position of the wing flaps and slats.

In response to an approaching stall condition, the stall warning system provided the following warnings:

- the red checked column ('red zipper') appeared on the lower part of the airspeed display on both pilot's primary flight displays (Figure 1);
- the stick shakers rapidly vibrated both pilots' control columns; and
- the cyan pitch limit indicators on both pilots' primary flight displays changed to red in colour at stick shaker activation.

Once an aircraft stalled, flashing red STALL annunciations appeared on both pilots' primary flight display, an aural warning (klaxon) sounded, and a vocal 'stall' warning was annunciated. If the aircraft remained in a stalled condition for 6 seconds (due to pilot inaction), the warning system operated a stick pusher actuator, which pushed the control columns forward to initiate a stall recovery manoeuvre. For the stick pusher to activate, the radio altitude had to be higher than 150 ft.

Aircraft performance

The operator's load sheet for the flight indicated that the weight of the aircraft was 48.7 tonnes and that its centre of gravity was 24.6% mean aerodynamic chord²⁰. Those values were confirmed by the FDR data.

The operator's take-off performance charts for Alice Springs runway 30 (with the air conditioning system on) indicated that the appropriate flaps setting was 7.9 degrees for 23°C outside air temperature and a 10 kts headwind. The maximum allowable aircraft weight for a takeoff in those conditions was 53.8 tonnes.

19 An aerodynamic stall involves a gross change in the airflow around the wing, which is characterised by a separation of the boundary layer from the upper wing surface, and results in a loss in lift.

20 The wing chord is a straight line joining the centres of curvature of the leading and trailing edges of the wing. The mean aerodynamic chord is the chord of an imaginary wing of constant section having the same force vectors under all conditions as those of the actual wing.

The quick access recorder showed that the flight crew entered the following speeds into the flight management computer for the takeoff:

- decision speed (V_1)²¹ of 138 kts
- rotation speed (V_R) of 141 kts
- take-off safety speed (V_2)²² of 146 kts.

Those speeds matched the interpolated speeds for an aircraft weighing 48.7 tonnes that were able to be derived from the 'Takeoff Speeds – Dry Runway' table in the *717 Flight Crew Operating Manual*.

The general performance charts in the *717-200 Flight Manual* indicated that the stalling speed for a 48.7 tonne aircraft with 8 degrees of flaps set (and therefore slats extended) was 121 kts.

The aircraft manufacturer advised that the angle of attack used by the flight control computers to activate the stick shaker with the flaps and slats extended would have been 16.3 degrees. That stick shaker angle of attack would have reduced to 9.5 degrees if the flight control computers' calculations were based on a slats-retracted schedule at the time the stick shaker activated.

The aircraft manufacturer also advised that the aircraft would have to have reached 20.9 degrees angle of attack for the aircraft to stall (and for the stick pusher to activate) with the flaps and slats extended. However, if the flight control computers' calculations were based on a slats-retracted schedule, then the stalling angle of attack would have reduced to 12.5 degrees.

The *717 Flight Crew Operating Manual* provided a table of stabiliser trim settings for maximum take-off thrust.²³ Interpolating from that table for an 8 degree flaps setting, the appropriate stabiliser trim setting was -2.6 degrees (aircraft nose up).

Aircraft system messages

The following advisory messages were observed by the flight crew on the 'engine and alert display' screen after the cessation of the stick shaker:

- PSEU FAIL.⁷ The activation of the PSEU FAIL advisory message indicated the failure or malfunction of a single non-redundant sensor, or an unrecoverable internal fault within the proximity sensing electronics unit (PSEU), resulting in a total loss of information regarding the position of the landing gear, cabin and cargo doors, or wing leading edge slats.²⁴

21 V_1 refers to the maximum speed at which a pilot can safely reject the takeoff.

22 V_2 refers to the lowest speed at which the aircraft complies with those handling criteria associated with the climb after takeoff following an engine failure. That speed should be achieved by 35 ft.

23 The incident takeoff did not use maximum thrust.

24 The aircraft manufacturer advised that the PSEU FAIL alert was designed to illuminate if the PSEU could not definitively determine the position of a component. The alert did not compromise the integrity of the position sensing capability of the remaining sensors.

- **WSHEAR DET FAIL.** The WSHEAR DET FAIL advisory message indicated that the reactive windshear detection and guidance system had failed for both flight control computers.
- **STICK PUSHER FAIL.** This advisory message indicated that the stick pusher had failed, or was close to failure, which would result in an uncommanded activation. The aircraft manufacturer advised that in this incident, the STICK PUSHER FAIL message was not caused by an active pusher failure but by the disagreement between the left wing slat's position sensor signal and the right wing slat's position sensor signal to the PSEU causing the flight control computers to inhibit the stick pusher.

Flaps and slats

Boeing 717 aircraft had hydraulically-powered trailing edge wing flaps and leading edge wing slats. Wing flaps and slats augment a wing's lift during slow speed flight, such as occurs during the takeoff, approach and landing phases of flight.

The leading edge slats could be selected to either fully extended or fully retracted. The trailing edge flaps could be extended incrementally from zero to 40 degrees. When the flaps/slats handle was selected to the up/retract position, both the flaps and slats were retracted. When the handle was selected to 0 degrees or greater, the flaps were set at the degrees set, the slats were fully extended. The maximum speed allowed with the flaps extended to up to 10 degrees was 280 kts.

There were five slat segments on the leading edge of each wing. Each wing contained two slats proximity sensors. As the slats moved, the two slats proximity sensors in each wing sent position signals to the PSEU. The PSEU sent signals to the flight control computers to display the position of the slats to the flight crew. The flight control computers used the flaps/slats position information (along with the angle of attack and horizontal stabiliser position) to continually monitor if the aircraft was approaching a stall condition.

The PSEU transmitted independent left and right wing slat position indications to both flight control computers. In the event that a slat position could not be conclusively determined, either due to a faulty sensor or wiring, the PSEU would default to the 'slat not-extended' indication.

If there was any mismatch between the left and right wing slats position information from the PSEU, the flight control computers would adjust their computations to the 'slats-retracted' schedule. Such an adjustment could result in stick shaker activation despite the aircraft not actually approaching a stall condition.

Engineering investigation

On arrival at Perth, the operator's engineers inspected the aircraft. The aircraft's centralised fault display system detected a PSEU fault caused by one of the left wing slats proximity sensors. The affected sensor was replaced.

The operator requested the aircraft manufacturer to analyse the event. The manufacturer reported that the PSEU logged a 'Left Slat Sensor "A" Fault' and that both flight control computers showed a PSEU-reported fault of 'Slat Position

Invalid' one second after the PSEU reported the 'Left Sensor "A" Fault' during the takeoff.

The aircraft manufacturer advised the ATSB that the logged left wing slats fault message indicated a problem with either the left slat 'A' proximity sensor, interconnecting wiring, or external electromagnetic interference altering the sensor inductance signal to the PSEU.

The aircraft manufacturer recommended that the PSEU and affected slats proximity sensor be forwarded to the component manufacturer for testing. The component manufacturer reported that no significant defects were found during those tests. The aircraft manufacturer also requested that the operator conduct a specified set of checks of the wiring from the left wing slats proximity sensors to the PSEU. No faults or defects were detected as a result of those checks.

The aircraft manufacturer also examined the design of the Boeing 717 aircraft in relation to the potential for interference between the PSEU and the flight control computers as a possible source of this incident and a similar incident involving the same operator in May 2006 (see the *Similar events* section below). That examination included a review by the component manufacturer of the relevant electromagnetic effects testing data and installation, and of the categories of the wires used in the left wire bundling from the PSEU to the slats sensors. No significant issues were identified. The type of proximity sensor installed on the aircraft was also 'deemed to be robust' by the aircraft manufacturer.

The aircraft manufacturer's examination concluded that:

It was decided, after review of all the items investigated in the design review, that there were no conclusive findings to establish a root cause of the 3 reported 717 events [see the *Similar events* section below]... . The [manufacturer's] team concluded that due diligence has been performed. In addition, there have been no further similar 717 events reported subsequent to the last one [the current incident].

Thus, it was concluded that for the case of the three events, and in the absence of further reports of similar 717 events, there does not seem to be a systemic problem for this issue in the 717 fleet.

Operator's procedures

Take-off procedure

The *normal takeoff* procedures in the *717 Flight Crew Operating Manual* included the following:

.....

4. PNF [pilot not flying] calls "V_R." PF [the pilot flying or handling pilot] verifies airspeed and smoothly rotates approximately 2.5°/sec to attain V₂ + 10 [kts] at 35 feet AGL [above ground level].

5. At positive rate of climb and V₂, PF calls "GEAR UP". PNF verifies positive rate of climb and moves gear handle to UP and calls "GEAR UP". PF maintains a minimum of V₂ + 10 [kts], which should not normally exceed 20° nose up.

Stall recovery procedure

The *717 Flight Crew Operating Manual* stated that the recovery from an approach to stall condition when the aircraft was in a take-off configuration was as follows:

First indication of approach to stall

- Apply max available thrust.
- Adjust pitch as required to minimize altitude loss or to provide obstacle clearance.
- Maintain existing flap/slat and gear configuration.
- If ground contact is imminent, apply max thrust (up to throttle mechanical stops).
- Accelerate to minimum maneuvering speed for existing configuration then adjust configuration as desired.

Similar events

The operator had previously reported two similar stick shaker events involving other Boeing 717 aircraft in its fleet.

On 15 September 2005, the stick shaker on aircraft registered VH-NXC²⁵ activated for approximately 3 seconds while descending through 800 ft on final approach in calm conditions. The slats were in transit at the time and a subsequent maintenance examination revealed a faulty right slat proximity sensor.

In addition, on 10 May 2006, the crew of the aircraft registered VH-NXG²⁶ observed an annunciation that the PSEU had failed at the top of descent. When configuring the aircraft for approach, the crew did not receive the expected confirmation that the leading edge slats had extended normally. A visual check confirmed that the slats had extended and the approach was continued. While on approach, the stick shaker activated on two occasions. The crew took immediate action to achieve a greater speed margin and landed the aircraft safely.²⁷

The aircraft manufacturer reported that a similar event also occurred in August 2001 involving a European airline. However, very little information was known about that event. The manufacturer stated that there had been no further similar events involving the aircraft type reported subsequent to the current occurrence.

A total of 156 Boeing 717 aircraft had been manufactured since 1998.

25 ATSB aviation occurrence 200504752 (available at www.atsb.gov.au).

26 ATSB aviation occurrence 200602812 (available at www.atsb.gov.au).

27 Another stick shaker event was reported by the operator in February 2006 (BO/200601076, also available at the ATSB web site). In that case, the output from the aircraft's angle of attack sensors became temporarily static during the climb, before recommencing normal operation during the subsequent immediate descent that was initiated by the flight crew. The event was not considered relevant to the current investigation.

ANALYSIS

Aircraft systems

There were three inputs to the flight control computers that could have resulted in a stick shaker activation: the position of the aircraft's horizontal stabiliser, the aircraft's angle of attack, and the position of its wing flaps/slats. The horizontal stabiliser was appropriately set at -2.7 degrees (aircraft nose up) and did not vary during the takeoff. The recorded angle of attack did not increase to the angle that should have been used by the flight control computers, given the configuration of the aircraft, to activate the stick shaker. However, the recorded values of the flaps and slats did vary. That variation was coincident with the stick shaker activation and would have then altered the angle of attack used by the flight control computers to activate the stick shaker.

The position of both wings' trailing edge flaps varied by 1 degree during the takeoff. It was probable that vibration and flexing of the aircraft's structure during the takeoff moved the flap positions sufficiently to vary the recorded values. However, a 1 degree variation of the flaps would have minimally influenced the angle of attack stick shaker schedule used by the flight control computers. Furthermore, the 1 degree extension of the left wing flaps at the time of the stick shaker activation would have required the aircraft to achieve a larger angle of attack to initiate the stick shaker than at the flap setting for takeoff. Therefore, the recorded movement of the left flap did not result in the stick shaker stall warning.

The slats on the left wing were recorded as not-extended at about the same time as the stick shaker activated. If the left slats had retracted, asymmetric aerodynamic forces, due to the uneven slat positions, would have caused the aircraft to roll to the left as there would have been a considerable reduction in lift produced by the left wing. The recorded data showed no significant change to the aircraft's roll attitude during the takeoff and climb and that there were only minor aileron movements from the crew to maintain a wings-level attitude, indicating that there were no asymmetric aerodynamic forces experienced. Therefore, it can be concluded with almost certainty that the recorded not-extended position of the left wing slats was an incorrect indication, and that the slats did not actually retract.

The logged left wing slats fault message indicated a problem with either the left slat 'A' proximity sensor, interconnecting wiring, or external electromagnetic interference altering the sensor inductance signal to the proximity sensing electronics unit (PSEU). The resulting PSEU FAIL advisory message was a direct result of that problem, and resulted in a disagreement between the slats position signals from the two proximity sensors in that wing. Consequentially, the PSEU transmitted the default not-extended slat position signal for the left wing to the flight control computers.

The flight control computers would have used the flaps-extended/slats-retracted stick shaker angle of attack schedule when they received different slat position signals for the left and right wing from the PSEU. As the angle of attack on the incident flight exceeded that derived by the flight control computers when the stick shaker activated, it is almost certain that the defaulted slats-retracted schedule resulted in the activation of the stick shaker.

Although the reason for the left wing slat sensor 'A' fault message could not be determined, as a result of the aircraft manufacturer's examination of this and all known previous similar incidents, the manufacturer concluded that there did not seem to be a systemic problem in the aircraft type.

Aircraft performance

At the time the stick shaker activated, the aircraft was 39 kts faster than the stalling speed for the aircraft's weight and flaps/slats settings. Furthermore, the maximum angle of attack achieved was 4.7 degrees less than the stalling angle of attack for the aircraft's weight and flaps/slats settings. The crew had selected the appropriate flap setting for the runway, wind and temperature, the aircraft was 5.2 tonnes under the maximum take-off performance weight, the aircraft was rotated at the appropriate rotation speed, an appropriate rotation rate was established, and the pitch attitude did not exceed the operator's specified maximum of 20 degrees nose up. In addition, the aircraft's airspeed was increasing and the aircraft was established in a positive rate of climb. Therefore, it is almost certain that the aircraft was not approaching an aerodynamic stall condition during the stick shaker activation.

Crew actions

The activation of the aircraft's stick shaker required the crew take immediate action to avoid the possibility of an aerodynamic stall. Even when presented with airspeed and aircraft attitude information that indicated that the aircraft was unlikely to be approaching an aerodynamic stall, the flight crew's actions to increase airspeed and reduce the aircraft's angle of attack ensured that the safety of the flight was not compromised.

By maintaining visual reference with the ground, the pilot in command minimised the risk of the aircraft contacting the ground during the recovery from the stick shaker activation. The decision to continue the flight to its intended destination was made after consideration and assessment by the flight crew of all of the available information.

FINDINGS

From the evidence available, the following findings are made with respect to the stall warning device event involving Boeing Company 717-200 aircraft, registered VH-NXE, which occurred at Alice Springs, NT, on 2 August 2006. They should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- It is almost certain that an incorrect left wing slat sensor signal was received by the proximity sensing electronics unit (PSEU) from one of the two left wing slats proximity sensors. Consequently, the different slat position signals from the two sensors in the left wing resulted in the PSEU defaulting to the 'slats not-extended' indication for the left wing.
- As a result of the different slat position signals sent by the PSEU for the left wing (slats not-extended) and right wing (slats extended), the aircraft's flight control computers used the flaps-extended/slats-retracted stick shaker angle of attack schedule, leading to stick shaker activation and other stall indications.

Other key findings

- The aircraft did not approach an aerodynamic stall condition at any time during the stick shaker activation.
- The crew used applicable aircraft take-off settings and performed the takeoff appropriately.
- The crew reacted appropriately to the stall warnings by increasing engine thrust and reducing the aircraft's pitch attitude.
- The pilot in command maintained visual contact with the ground during the stick shaker event.

SAFETY ACTIONS

The following local safety actions were communicated to the Australian Transport Safety Bureau during the investigation.

Operator

The operator circulated the circumstances of this stall warning device event to all of its Boeing 717 fleet pilots for information.

Aircraft manufacturer

The aircraft manufacturer reviewed the design of the Boeing 717 aircraft in relation to the potential for interference between the proximity sensing electronics unit (PSEU) and the flight control computers, the quality testing and installation of the slats sensors by the component manufacturer, and the wire categories used in the left wire bundling from the PSEU to the slats sensors. That examination concluded that there was no systemic problem with those components.