Australian Government
Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation
AO-2008-064
Final

Stickshaker activation
Boeing 717-200, VH-NXE
Alice Springs, NT
18 September 2008

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Figures 1 and 2: Google images
Figure 3: The Boeing Company

Abstract

On 18 September 2008, a Boeing Company 717-200 (717), registered VH-NXE, was being operated on a scheduled passenger flight from Cairns, Queensland to Alice Springs, Northern Territory. There were 70 passengers, four cabin crew and two flight crew on board. During the manually-flown visual approach by the pilot in command (PIC) to runway 30 at Alice Springs Aerodrome, the stickshaker activated. The pilot flying lowered the nose while continuing the turn onto final. The stickshaker activated again before the flight crew stabilised the approach to within the operator's criteria and landed without further incident.

The investigation found that the stickshaker activated because of a combination of bank angle, high nose-up pitch change rate and airspeed slightly below the approach speed. The aircraft was higher, faster and closer to the aerodrome than was suitable for the direct-to-final approach being attempted. The autothrottle was inadvertently not engaged by the flight crew after the automatic flight system was disconnected earlier in the approach, which contributed to the airspeed reduction. The PIC's response to the stickshaker did not conform to the aircraft manufacturer's procedures.

The investigation also found that the PIC's judgement and monitoring ability were probably adversely affected by personal and work stress and associated fatigue, although the duty roster met the necessary standards. Pilots operating within flight and duty time limitations can still experience fatigue. Responsibility for adequate flight crew wellbeing before flight rests with both operators and their pilots.

The investigation did not identify any organisational or systemic issues that might adversely affect the future safety of aviation operations. However, in response to this occurrence, the operator proactively issued a number of notices to pilots to enhance pilot flight mode annunciator and auto mode awareness in the 717, to highlight the aircraft's buffet protection system and to discuss recent stickshaker events, and to describe the stall recovery procedure in the 717. In addition, the operator amended a number of its command upgrade and recurrent simulator training requirements and worked with the aircraft manufacturer to reduce the incidence of stickshaker events across the operator's 717 fleet.

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

Sequence of events

On 18 September 2008 at 1135 Eastern Standard Time[1], a Boeing Company 717-200 (717) aircraft, registered VH-NXE (NXE), departed Cairns Aerodrome, Queensland on a scheduled passenger flight to Alice Springs, Northern Territory. On board the aircraft were 70 passengers, four cabin crew and two flight crew. The pilot in command (PIC) was the pilot flying.

The flight crew reported that the departure and cruise phases of the flight were uneventful. For the arrival at Alice Springs, they planned a visual approach using the flight management system (FMS) to track direct to the airport with provision to track for a 3 NM (6 km) final to runway 30. Given the reported wind conditions and high temperature, the flight crew expected moderate turbulence during the descent. Descent from flight level (FL)[2] 360 was initiated at 1252 Central Standard Time[1] when the aircraft was 100 DME[3] (185 km) inbound on the 055 radial[4]. The elevation of Alice Springs Aerodrome was 1,789 ft above mean sea level (AMSL).

At 1303:19, the aircraft passed 11,000 ft on descent at 28 DME (52 km) when air traffic control (ATC) advised the flight crew to expect a landing on runway 30.

When the flight crew reported approaching 7,000 ft, ATC cleared the crew to continue the descent to 6,500 ft. That descent limit was for procedural separation from a departing aircraft, which had been cleared to 5,500 ft. The average rate of descent of the aircraft when approaching 6,500 ft was about 1,500 ft/min.

At 1306:29, when the aircraft was 14 DME (26 km), ATC cleared the flight crew to conduct a visual approach[5] to runway 30 and from 6 miles (11 km) to track for a right base to runway 30. The recorded data showed that the aircraft left 6,500 ft (4,700 ft AAL[6]) on descent at 1307:12 when the aircraft was 10 DME (19 km). The flight crew reported that the delay in initiating the descent was due to an oversight when selecting the target altitude of 2,400 ft in the flight control panel (FCP).

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[1] The 24-hour clock is used in this report to describe the local time of day, Eastern Standard Time (EST) and Central Standard Time (CST), as particular events occurred in Queensland and Northern Territory respectively. Eastern Standard Time was Coordinated Universal Time (UTC) + 10 hours. Central Standard Time was Coordinated Universal Time (UTC) + 9.5 hours.

[2] A flight level is a level of surface of constant atmospheric pressure related to datum of 1013.25 hectopascals. FL 360 equated to 36,000 ft in the international standard atmosphere.

[3] DME refers to Distance-Measuring Equipment, which in this context is used as a unit of distance in nautical miles from a ground-based navigation aid located near the aerodrome.

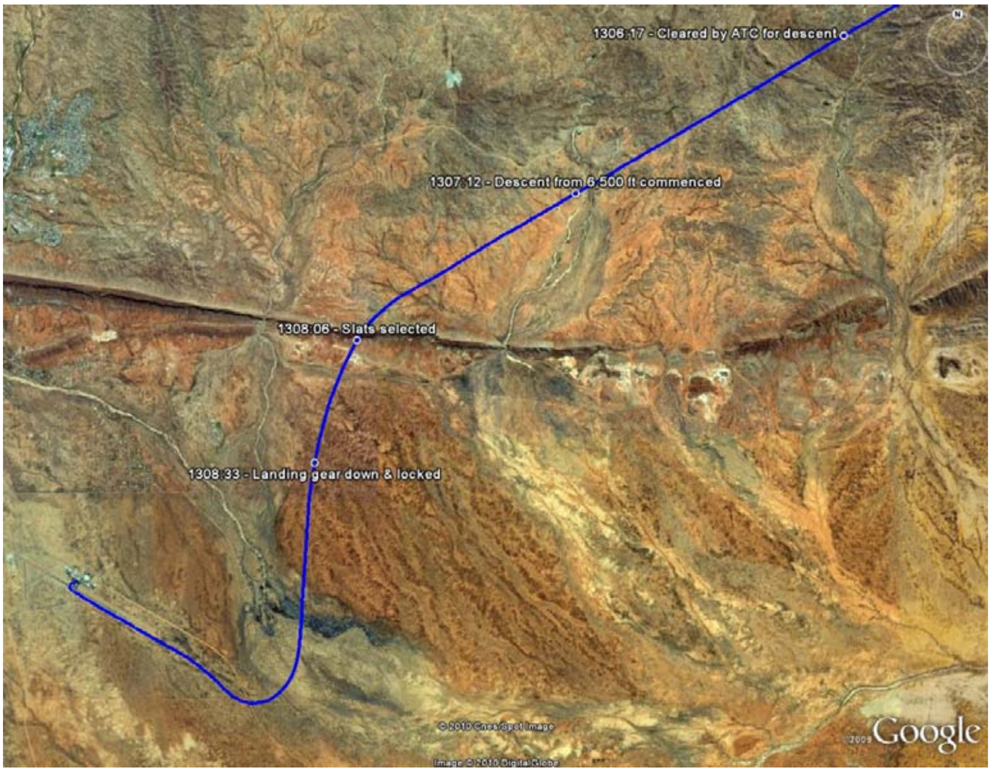
[4] A radial is a magnetic bearing extending from a ground-based point-source navigational aid such as a very high frequency omnidirectional radio range (VOR).

[5] A clearance to conduct a visual approach for an aircraft operating under the instrument flight rules by day, constitutes a clearance to descend as required, remaining not less than 500 ft above the lower limit of controlled airspace and not below the lowest altitude permissible for flight under the visual flight rules.

[6] AAL is the height above aerodrome level.

The PIC recounted that due to being high on profile, he disconnected the autothrottle[7] and reduced engine thrust. The recorded N1[8] correspondingly reduced from 66% to 28% and the aircraft's spoilers[9] were deployed for 45 seconds. The PIC's recollection was that at some point, PROF[10] was selected on the FCP, which should have reengaged the autothrottle.

Figure 1: Initial approach track



At 1307:50, when the aircraft was approaching 7 DME (13 km), ATC cleared the flight crew to track direct to a right base position for runway 30. The recorded data showed that at about that time, the aircraft was passing 4,500 ft (2,700 ft AAL) and the aircraft's speed was 272 kts computed airspeed[11] (CAS) and 292 kts groundspeed.

The PIC asked the copilot to select the direct-to-intercept for the 3-mile (6 km) final on the FMS and to hard select[12] 190 kts. The copilot reported complying with the

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[7] An automated engine power control system that is electro-mechanically linked to an aircraft's flight management systems so that in general terms, engine thrust is varied automatically to maintain aircraft airspeed and/or profile.

[8] N1 refers to fan or low pressure compressor speed, which is an indicator of engine thrust.

[9] Spoilers are moveable surfaces on the upper rear surface of each wing which, when raised, reduce lift and increase drag. When used as speed brakes, spoilers can increase the rate of descent and/or decrease speed.

[10] PROF represents vertical profile, one of a number of modes in the aircraft's flight management system (FMS).

[11] Airspeed sensed and computed by the digital air data system.

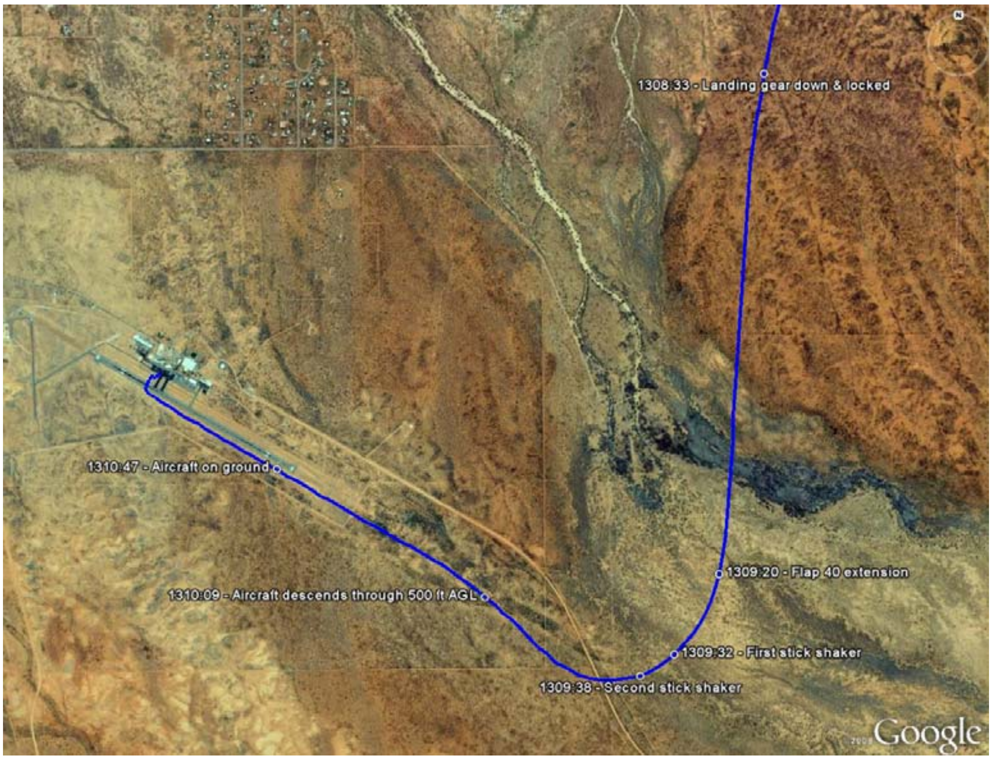
[12] Hard select refers to the practice of programming a specific speed, rather than allowing the FMS to set the speed.

instruction, but that the FMS generated an intercept from the opposite direction, probably because the aircraft was too close and fast for the intended intercept. In response, the PIC disconnected the autopilot to manually fly the approach.

During the turn to track to the south, the crew extended the leading edge slats, landing gear and some wing flap to slow the aircraft. The PIC had asked for FLAP 18, but the recorded data showed that the flaps actually only extended to FLAP 13. The copilot reported becoming aware of the mis-selection when selecting FLAP 40 later during the approach.

By1309:04, the aircraft was established on the direct track to the final intercept position at 183 kts CAS, 210 kts groundspeed and passing 3,000 ft (1,200 ft AAL). The copilot set up the runway track on the FMS to assist the PIC's orientation.

Figure 2: Final approach track



At 1309:20, FLAP 40 (full flap) had finished extending and the PIC initiated a right turn to intercept the final approach track. The aircraft was passing 2,800 ft and the speed was 157 kts CAS and 180 kts groundspeed. The recorded bank angle varied between 26° and 29°. During the turn, the PIC was looking outside to maintain visual contact with the runway and the copilot was performing some of the pre-landing checklist actions.

The flight crew reported that, during the turn, the stickshaker[13] momentarily activated. The PIC reported looking at 'the screen' (flight instrument display) and,

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13 The stickshaker was a tactile warning to alert the flight crew that the aircraft was near an aerodynamically-stalled condition of flight.

seeing the ‘red zipper’[14] up, responded by lowering the nose and advancing the throttles. No attempt was made to reduce the bank angle.

Analysis of the recorded data showed that at 1309:32, the stickshaker activated as the aircraft was passing 950 ft AAL on a heading of 223° magnetic (M) with a recorded bank angle of 28° and airspeed of 135 kts. Following the stickshaker activation, the recorded pitch angle decreased from an average 6° to -4° with no immediate recorded throttle movement and no increase in the N1 value, which was then about 36%. At 1309:35, the airspeed had reduced to a recorded value of 131 kts with a bank angle of 30°.

The PIC recalled realising that the autothrottle was not engaged and selected PROF, or asked the copilot to select PROF, to reengage it.

The flight crew reported that shortly after the first stickshaker activation, the stickshaker momentarily activated again. Correspondingly, the data showed that at 1309:38, the stickshaker activated again as the aircraft was passing 850 ft AAL with a recorded bank angle of 27° and airspeed of 134 kts. The recorded pitch angle was 0° and the rate of descent was 1,800 ft/min. The nose was lowered again and the recorded airspeed increased to vary between 140 and 145 kts. Shortly after, the recorded throttle position increased and N1 reached a high of about 76%.

By the time the aircraft was 500 ft AAL, it was aligned on the runway’s extended centreline and descending at about 900 ft/min.

At 1310:56 the aircraft landed on runway 30.

Personnel information

Pilot in command

The PIC held an Air Transport Pilot (Aeroplane) Licence (ATPL(A)) that was issued in 1999 and a 717 type rating that was issued in 2006. The PIC had a total of about 10,000 hours aeronautical experience, including 1,000 hours on the 717. The PIC’s 13 years employment with the operator included operations as a copilot on various aircraft types, including the 717 and British Aerospace BAe 146.

Transition training to the 717 was conducted by a third-party training provider in Australia during March and April 2006. It included ground and flight training that was conducted on a flight-training device and full flight simulator. The training records indicated successful completion of stall recognition and recovery and there was no record of any significant difficulties. The PIC reported that stickshaker activation during simulator training always occurred during takeoff. The PIC’s operations as a copilot on the 717 ceased in July 2007, when the PIC took a period of extended leave.

The PIC reported that the extended leave was taken to facilitate the conduct of single-pilot, multi-engine instrument-flight-rules flights with a general aviation operator, in order to increase in-command flying hours. Those flying hours were

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14 The red zipper was the red checker column on the airspeed representation on the primary flight display, which graphically-displayed the margin between the stickshaker activation speed and the current airspeed on the primary flight displays.

necessary in order for the PIC to meet the amount considered by the operator to be the minimum required by the Civil Aviation Safety Authority (CASA) for a command on the 717. At that time, there was reported to have been limited opportunity for pilots to operate in-command-under-supervision (ICUS) with the operator.

The PIC returned to the operator in May 2008 and began line training for a 717 command. In July 2008, after a number of training flights, the PIC was cleared to line as a 717 captain.

On 20 August 2008, CASA issued the PIC with a Class 1 Medical Certificate. There were no recorded restrictions.

Copilot

The copilot held an ATPL(A) that was issued in 2006 and a 717 type rating that was issued in 2007. The copilot had a total of 3,800 hours, including 470 hours on the 717.

The copilot was trained for transition to the 717 by a third-party training provider in Australia during November and December 2007. The training records indicated successful completion of stall recognition and recovery. There was no record of any significant difficulties.

In January 2008, the copilot began line training with the operator on the 717 and was cleared to line as a 717 first officer.

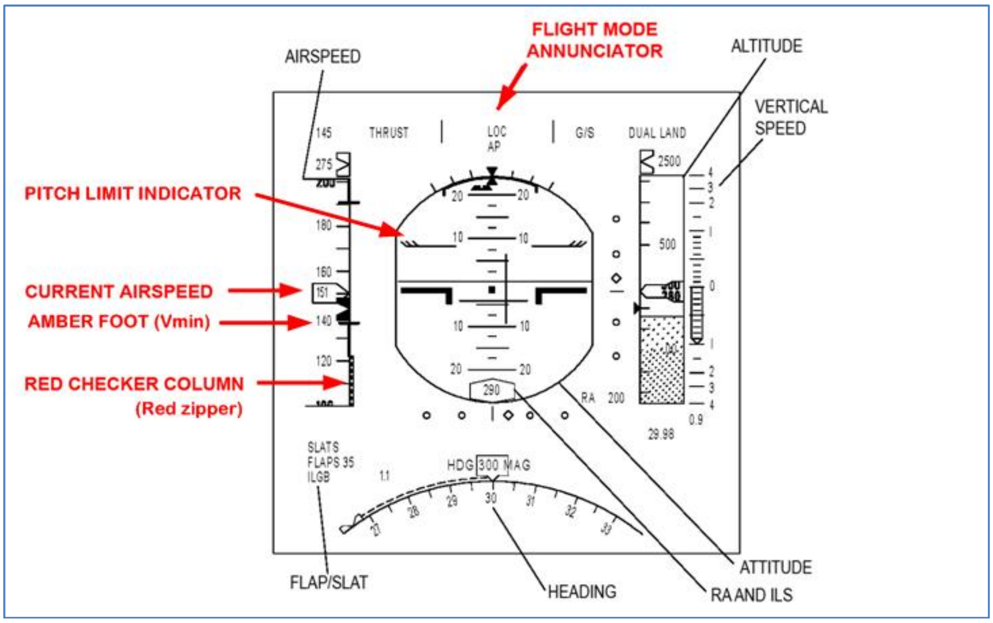
The copilot held a CASA-issued Class 1 Medical Certificate.

Aircraft information

Flight instrumentation

The aircraft was equipped with an electronic instrument system (EIS) that consisted primarily of six flat-panel liquid crystal display units (LCDU) on the instrument panel. Those LCDUs included a primary flight display (PFD) for the pilot and a PFD for the copilot (Figure 3). The information that was displayed on the PFDs included: an indication of the aircraft’s attitude, airspeed, altitude, and flight mode; and a stall annunciation.

Figure 3: Primary flight display



During an approach, the pitch limit indicator (PLI) on each pilot's PFD indicated the difference between the aircraft's angle of attack[15] and the stickshaker angle of attack. The PLI, which was normally cyan in colour, turned amber as the aircraft approached the stickshaker angle of attack and red at the stickshaker angle of attack. The PLI was for information only and was not to be used for guidance command.

Both PFDs displayed the red checker column that moved vertically on the airspeed tape, graphically displaying the margin between the stickshaker activation speed and the current airspeed. The margin between the aircraft's current airspeed and the stickshaker speed was dynamic and displayed throughout the flight and while manoeuvring to land. In addition, the current airspeed indication, shown at the centre of the airspeed tape, would turn amber when the airspeed was below the minimum operating speed (Vmin) and red when the stickshaker activated.

Automatic flight system

The aircraft was equipped with an automatic flight system (AFS). The AFS processed data from a number of sources to provide various outputs for the control of pitch, roll, yaw, thrust and stall warning, and for limiting the travel of the rudder at higher speeds. The autoflight controls were located on the FCP and annunciations were displayed on the PFD.

The AFS included an autothrottle system (ATS), which was engaged by the AUTO FLIGHT switch on the FCP and disconnected through switches on the throttles. ATS annunciations were displayed on the PFD. If the ATS was disconnected, a red-coloured ATS OFF annunciation flashed three times on the flight mode annunciator (FMA) at the top the PFD. When selected (above 400 ft above ground level), the PROF switch on the FCP engaged FMS vertical profile guidance and activated the ATS.

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15 The angle of attack was the direction of the airflow relative to the chord of the wing.

At a speed not less than Vmin-5kts the ATS entered a low-speed protection mode, which adjusted the thrust from the engines to hold the aircraft speed at the FMS-calculated Vmin.

Flight management system

The aircraft was equipped with a FMS for flight planning, navigation, performance management, aircraft guidance and flight progress monitoring. Flight crew input was provided through two multifunction control and display units (MCDUs) and the FCP. Flight progress was monitored through the MCDU and EIS displays.

Critical speeds

The Vmin was the higher of either 1.23 times the stall speed (Vs) or 1.3 times the load factor (g) to stickshaker activation. Vmin was calculated by the FMS based on the entered aircraft weight and configuration and was displayed on the PFD as an amber foot. In this case, Vmin for the approach was 132 kts.

The target speed for approach (Vapp) defaulted to Vmin+5 kts, and the flight crew could increase that speed if they assessed that was operationally necessary. During this approach, the crew used the default speed of 137 kts. The aircraft manufacturer recommended that, depending on wind conditions, Vapp should be increased to either the greater of reference approach speed (Vref) + 5 or Vref + wind additive (one-half of the steady state wind greater than 20 kts or full gust, whichever was greater up to a maximum of 20 kts). With FLAP 40 extended, Vref was equal to Vmin.

For the aircraft's weight at the time of the stickshaker activation, the stall speed in a 28° bank turn in balanced flight was calculated to be 112 kts.

Stall protection system

The aircraft was equipped with a stall protection system (SPS) that provided advance warning of an impending stall, and recovery post stall. The SPS used a combination of angle of attack (alpha) and alpha rate (rate of alpha change in degrees/sec), flap/slat configuration, and horizontal stabiliser position computed in a complex logic equation.

The first warning generated by the SPS was the stickshaker, which vibrated each pilot's control column. The aircraft was not in a stalled condition when the stickshaker activated, but was operating outside of the operational flight envelope.[16]

The second level of warning occurred if alpha increased beyond the stickshaker figure. In that case, a red-coloured STALL annunciation appeared on the PFD, accompanied by an aural STALL STALL warning and klaxon. The aircraft was equipped with a stick pusher that, in the event of an aerodynamic stall, automatically decreased alpha to facilitate recovery.

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16 According to the aircraft manufacturer, activation of the stickshaker indicated that the aircraft was operating in the 'limit flight envelope'.

The aircraft manufacturer calculated that the stickshaker would not normally activate at the angle of bank and airspeed recorded in this occurrence, but that the pitch changes increased the g[17] loading and produced a high rate of change of alpha.

The aircraft manufacturer calculated that, at a Vmin of 132 kts, the margin to stickshaker was 1.4 g; and at a Vmin+5 kts, the margin was 1.5 g. Given that a coordinated 30° bank turn will result in a 1.15 g load factor, there should have existed an adequate margin between the manoeuvre being flown and the stickshaker activation speed. However, the recorded data showed that the g loading increased to 1.35 g and that there was a change in aircraft pitch attitude from 2° to 6° in 1 second. That combination, at an airspeed near Vmin, would have been sufficient to activate the stickshaker to alert the crew of a rapidly approaching stall.

Meteorological information

The area forecast applicable to the descent into Alice Springs was valid from 0830 to 2030 CST and predicted the wind below 10,000 ft to be from between west and north-west at 15 to 25 kts. There was no forecast significant weather, but moderate mechanical turbulence was expected below 8,000 ft on approach into Alice Springs. An amended area forecast that was valid from 1240 CST had no significant changes.

The aerodrome forecast (TAF) for Alice Springs that was valid at the time of the occurrence predicted visibility greater than 10 km and no cloud below 5,200 ft with no significant weather (CAVOK). The wind was expected to be from 325° M at 17 kts, gusting to 27 kts.

The routine weather report (METAR) for Alice Springs at 1300 recorded CAVOK conditions, with a wind from 305° M at 15 kts and a temperature of 36 °C.

The 1-minute data recorded at Alice Springs at 1310 recorded the wind from 335° M at 20 kts. The flight crew reported that the conditions were gusty with moderate turbulence, and the recorded data showed abrupt variations in the aircraft's vertical and lateral acceleration.

Recorded data

The aircraft was fitted with a cockpit voice recorder (CVR), solid state flight data recorder (SSFDR) and a digital aircraft condition monitoring system recorder (DAR). The CVR and SSFDR had a storage capacity of 2 hours and 25 hours respectively and were overwritten before the Australian Transport Safety Bureau (ATSB) accessed the data. The DAR data, which was used by the operator for flight operations quality assurance (FOQA), contained less parameters than the SSFDR. The operator had retained the DAR data that included the incident flight and provided that to the ATSB for analysis.

The ATSB analysis included the verification of the data, the production of data listings and graphical plots, and the animation of the approach sequence. The DAR did not record the activation of the aircraft's stall protection system as a discrete parameter but, in conjunction with the aircraft manufacturer, the investigation was

[17] G-loading is the value of acceleration expressed in multiples of gravitational acceleration, where 1 g is the acceleration due to the Earth's gravity.

able to identify likely stickshaker activation points from the recorded parameters that were used to activate the stall protection system.

It was established that the activation of the stickshaker was consistent with the design of the stall protection system. The stickshaker activation was confirmed as momentary and the aircraft was not aerodynamically stalled during that time.

The SSFDR data from a stickshaker activation in another 717 on 19 July 2009 during an approach into Kalgoorlie, Western Australia was obtained by the ATSB. Refer to the following discussion in *Other occurrences* for more information.

Organisational and management information

Operator procedures

Economy of operation

On 8 September 2008, the operator published advice for 717 pilots regarding block time and fuel burn management. The notice to pilots provided background including that:

> The aim should always be to fly the aircraft at its most economical profile and achieve an on-time arrival...
>
> Fuel is expensive and becoming more expensive on a daily basis. If the same task can be achieved for a reduced fuel burn, then it behoves each and every crew member to strive to achieve this outcome.

The notice to pilots went on to provide advice regarding adherence to scheduled on-blocks times, the application of cost indexes and the selection of optimum cruise levels.

The pilot in command (PIC) reported that there was, in his words, a ‘push’ by the operator to delay configuring the aircraft for landing, thereby saving fuel. The operator reported that there was no advice provided relating to delaying the configuration of aircraft for landing.

Circling approaches

The operator’s *B717 Aircraft Operating Procedures* manual contained procedures and techniques relating to manoeuvring within the circling area of an aerodrome with the intention of landing. Those techniques included:

> The aircraft should be progressively configured to arrive in the circling area with Flap18/EXT and the gear down with the Landing checklist completed to FLAP.
>
> When the PF [pilot flying] is the “inside” pilot ie closest to the runway, the PNF [pilot not flying] must continually monitor speed, height (including obstacle clearance height) and sink rate, and call any exceedances beyond the normal limits...

> When the PF is the 'outside' pilot, he/she must fly at the required height, speed and track primarily with reference to instruments until such time the runway is acquired during the base turn (generally about 90° around the turn)... The PNF must still monitor speed, bank angle and sink rate.
>
> Make full use of the ND [Navigation Display] during downwind, base and final. If a non-database approach has been flown the runway should be selected from the STAR page of the FMS during the FMS setup to provide an extended runway centreline.
>
> The maximum bank angle limit should be targeted in the initial part of the turn onto base and final to ensure that the runway centreline will not be overshot. If this occurs, bank must not be increased beyond the bank angle limit.
>
> Make use of the trend vector to establish the angle of bank required to intercept the runway centreline.

The PIC reported that it was the first right-base to runway 30 at Alice Springs that he had conducted. The copilot reported having been involved in a number of visual approaches to runway 30 on arrival from Cairns and that each time a base position had been inserted in the FMS. There was no procedural requirement to set up a visual approach with a base point.

Approach

The operator's *Aircraft General Operating Procedures* contained procedures relating to stabilised approaches. Those procedures included that:

> Below 1000ft Above Aerodrome Level (AAL) the rate of descent is not to exceed 1000ft/min, except as noted below. The aircraft is to be stabilised in the landing configuration by 400ft AAL.
>
> An approach is considered to be Stabilised when all of the following criteria are met:
>
>> The aircraft is established on the runway centreline with only small changes in heading or pitch required to maintain the approach path
>>
>> The aircraft speed is not above Vapp +10kts and not less than Vapp -5 kt
>>
>> The aircraft is in the landing configuration
>>
>> Momentary excursions of slope and speed, caused by wind gusts or turbulence, are acceptable.

The missed approach criteria required the execution of a missed approach if the aircraft was not stabilised at or below 400 ft AAL. Both pilots reported that the aircraft was stabilised by 500 ft AAL and that there was no apparent need during the approach for a go-around to be conducted.

Aircraft manufacturer procedures

The *717 Flight Crew Operating Manual* was produced by the aircraft manufacturer and contained procedures and techniques for recovery from an approaching stall. The procedure at the first indication of an approach to the stall in the takeoff, approach, landing or go-around configuration was:

> Note: If in a turn, Pilot Flying calls "HDG HLD"
>
> - 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 manoeuvring speed for existing configuration then adjust configuration as desired.

Additional information

Other 717 stickshaker occurrences

In the 2 years prior to the occurrence, the operator had recorded six 717 stickshaker events in their occurrence database. Three of those events occurred during operation of the aircraft within the 717's operational flight envelope and were related to sensor anomalies. Two of the events were related to flight crew being slow to react to decreasing airspeed and the remaining event was the result of rapid spoiler application.

On 19 July 2009, the flight crew of a 717 aircraft, registered VH-NXG, experienced a stickshaker activation during manoeuvring to land at Kalgoorlie/Boulder Aerodrome, Western Australia. The pilot flying had over-shot the centreline of the runway and was applying a bank angle of 27° to regain the centreline prior to landing. The stickshaker activated when the pilot flying applied further back pressure on the control column to reduce the aircraft's rate of descent. The event occurred at a height of 618 ft above ground level at a computed airspeed of 142 kts. The autothrottle was engaged throughout the approach and an increase in thrust was recorded at the same time the stickshaker activated.

Human factors

Flight and duty time limitations

The flight crew's flight and duty times were subject to a CASA-issued exemption from the limitations set out in Civil Aviation Order 48 (CAO 48). That exemption imposed a number of conditions on crews' daily flight and duty times, as well as limits on cumulative flight and duty time in a variety of consecutive-day periods.

The stipulated nominal time free of duty prior to a duty was 10 hours, but when the time free of duty included the period between 2200 and 0600, the time free of duty could be reduced to 9 consecutive hours.

The incident occurred on a Thursday. In the preceding week, the PIC had the Friday, Saturday, Sunday and Monday as rostered days off. On Tuesday the PIC signed on in Darwin at 0517 and completed sectors from Darwin to Gove and Gove to Cairns, with a total recorded flight time of 2 hours 49 minutes and duty time of 5 hours 06 minutes. On Wednesday, the day before the incident flight, the PIC signed on in Cairns at 1631 and completed the sectors Cairns to Gove and Gove to Darwin, before signing off at about 2057. The total recorded flight time in that instance was 2 hours 48 minutes and duty time 4 hours 55 minutes.

The PIC was on a 'reserve day'[18] on the day of the incident but, with some notice, was assigned to operate the sectors Darwin to Cairns and Cairns to Alice Springs. The recorded sign-on time was 0601, the total recorded flight time 4 hours 37 minutes, and the duty time 7 hours 26 minutes.

In the week preceding the incident, the copilot had the Friday and Saturday as rostered days off. The copilot then completed a 2-day trip to Cairns, followed by a reserve day. On Wednesday, the day before the incident, the copilot signed on at Darwin at 0445 and completed a return trip to Alice Springs before signing off at 1413. On the day of the incident the copilot signed on at 0600, and operated sectors from Darwin to Cairns and Cairns to Alice Springs with the PIC.

Fitness for flight crew duties

The CAO 48 exemption included a proviso for adequate flight crew well-being before flight as follows:

> A flight crew member shall not knowingly operate an aircraft and an operator shall not knowingly require or knowingly permit a flight crew member to operate an aircraft unless at the start of any duty period:
>
> (a) the operator has provided opportunity for and the flight crew member has taken adequate rest;
>
> (b) the operator has provided opportunity for and the flight crew member has taken adequate sustenance; and
>
> (c) the flight crew is free of any fatigue, illness, injury, medication or drug which could impair the safe exercise of his or her licence privileges.

Stress

The PIC reported feeling under a good deal of stress at the time of the incident, due to both personal and work-related reasons. The PIC recalled that, during the incident flight, he had been thinking about those stresses and believed that this might have contributed to the event by distracting him prior to descent.

A study completed in the United States on Coast Guard pilots indicated personal stress influenced self-perceptions of flying performance, most notably the sense of

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18 The pilot is available for duty, but not rostered to fly.

‘not feeling ahead of the game’.[19] In addition to this, pilots reported that personal stress led to fatigue and feeling tired due to disrupted sleep, as well as intruding thoughts during periods of low workload.

The copilot reported experiencing no significant stress during the flight.

Fatigue

The PIC reported staying at temporary accommodation and sleeping on average for only 4 hours a night. The PIC reported feeling drowsy during the day on a regular basis, especially between 1300 and 1500. The PIC recalled not getting to bed until 2300 the night before the incident, and getting up at 0430 on the day of the occurrence in order to be at the airport to start duty at 0600. That resulted in a sleep opportunity of just 5.5 hours.

Generally speaking, most people require at least 8 hours of sleep per night in order to sustain optimum alertness. If a person obtains less sleep than what they need over a period of time, they will become sleep-deprived. Compared to people who are well-rested, people who are sleep-deprived think and move more slowly, make more mistakes and have memory difficulties.

The PIC considered that fatigue was a factor during the approach into Alice Springs, in that it affected the PIC’s clarity of judgement and concentration. The PIC reported feeling ‘behind the aircraft’ due to a lack of concentration during the approach.

The operator did not have a formal fatigue management system, nor were they required to have one by aviation regulation. There was an informal operator policy that allowed flight crew to report being sick due to stress or fatigue.

Workload and attention

Both crew members reported their workload as being higher than usual during the approach to Alice Springs. They reported that this was due primarily to the high, fast, and tight approach being attempted. The PIC was manually flying the aircraft from the left seat, which made the right turn onto final harder to judge, as it meant looking out the opposite side of the aircraft to intercept the final approach track. This was exacerbated by the acute intercept angle. Disconnection of the automation also meant the pilot was manually controlling the heading, altitude, thrust and speed.

The copilot was completing checklist items during the turn onto final and, due to the compressed nature of the approach, the configuration of the aircraft was being done out of the usual order. While this did not present a significant problem on its own, it probably increased the copilot’s workload and resulted in more time concentrating on completing cockpit tasks and less time scanning the flight instruments. The copilot’s mis-selection of the flap during the approach could also be attributed to workload.

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[19] Fiedler, E.R., Della Rocco, P., Schroeder, D.J., & Nguyen, K.T. (2000). *The relationship between aviators’ home-based stress to work stress and self-perceived performance* (DOT/FAA/AM-00-32). Washington, DC: FAA Office of Aviation Medicine.

ANALYSIS

Introduction

The activation of a stickshaker indicated that the aircraft was operating outside of its operational flight envelope. In this event, there were two momentary activations of the stickshaker during the turn onto final approach while the aircraft was around 900 ft above aerodrome level and descending at about 1,800 ft/min. The aircraft was not aerodynamically stalled at any time. The following analysis will identify the safety factors in the development of the event and in the flight crew response to the stickshaker warnings.

Stickshaker activation

The sequence of events that were particularly relevant to the stickshaker activations commenced when air traffic control (ATC) held the aircraft at 6,500 ft due to opposite-direction traffic. About 1 minute later, ATC cleared the crew for a visual approach, which was a clearance to descend as required. The descent was further delayed by the flight crew's oversight during the selection of the lower target altitude in the flight control panel (FCP). The aircraft's descent had now been delayed by about 2 minutes, which at the aircraft's average descent rate of about 1,500 ft/min, corresponded to an excess of about 3,000 ft in height than desired, and necessitated a higher descent rate with associated higher speed to recover the desired profile.

Following the clearance to conduct a visual approach, ATC cleared the crew to track for a right base. Instead of tracking for a right base, the pilot in command (PIC) tracked direct to a 3-mile (6 km) final intercept in accordance with the planned approach. Aside from the non-conformance with the clearance, the proximity to the aerodrome created a situation where the aircraft was intercepting final approach at an acute angle, relatively close to the aerodrome, without a base leg. It could be expected that the conduct of a base leg would have assisted the flight crew in correctly judging the descent profile and timing the turn to intercept final.

The overall effect of the delayed descent and direct-to-final tracking from 6 DME (11 km) was that the aircraft was higher, faster and closer to the aerodrome than was suitable for the approach from that direction. Those factors would have contributed to a higher flight crew workload and increased the risk of going through the runway centreline during the turn.

The aircraft's flight management system did not generate the intended track to the 3-mile (6 km) final intercept point. That should have indicated to the crew that some parameters for the intended approach were marginal and acted as a trigger for the crew to change their plan. Instead, the PIC elected to disconnect the automatic flight system and fly the remainder of the approach manually. The PIC perception of the operator's fuel-saving directions might have influenced his decision to persist with the planned approach rather than extending the circuit, but there was no evidence that the operator's policies were unreasonable.

The PIC thought that the autothrottles were engaged and were therefore assisting with automatic speed control for the approach. However, the autothrottles were not engaged and, at the estimated time of stickshaker activation, the airspeed decreased to just below the approach speed (Vapp) of 137 kts. The airspeed was allowed to further decay to a minimum recorded value of 131 kts, three seconds later.

During the turn to intercept final approach, the combination of a 28° bank angle, a high rate of nose-up pitch change and an airspeed below Vapp contributed to activation of the stickshaker.

The decrease in the margin between the current airspeed and the stickshaker speed depicted by the 'red zipper' on the primary flight display was not detected by the flight crew prior to stickshaker activation. That was attributed to the relatively high pilot workload and diversion of attention to other tasks at that time.

Response to the stickshaker

The PIC responded to the initial activation of the stickshaker by immediately lowering the nose of the aircraft. That action reduced the angle of attack and stopped the stickshaker. However, the stickshaker activated again momentarily, and there was no record of throttle application until after the second stickshaker.

A comparison of the PIC's actions and the relevant aircraft manufacturer's procedures shows that the PIC did not comply with the first two elements of the manufacturer's checklist: that was, calling 'heading hold' and applying maximum available thrust. Heading hold required rolling out of the turn, which would have reduced the angle of attack and g loading and increased the margin over the stall. The application of maximum available thrust would have increased the airspeed and further improved the margin over the stall. Had the PIC rolled out of the turn and applied maximum thrust, the risk of an aerodynamic stall would have been reduced and the second stickshaker would probably not have occurred.

There was no clear explanation for the PIC not complying with the manufacturer's procedure in response to the stickshaker activations. However, possible influences might have been a lack of exposure to stickshaker activations on approach during training, and the human factors elements discussed in the following analysis titled *Human factors considerations*.

While the PIC's actions were sufficient in this case to recover from a developing stall situation, it is vitally important that flight crews respond to stickshaker activations in accordance with the stipulated procedures. Those procedures reduce the possibility of an unsafe condition of flight deteriorating into a loss of aircraft control.

Human factors considerations

The PIC reported being under a good deal of stress at the time of the incident, experiencing fatigue at the time, and feeling behind the aircraft during the approach. It is likely that those factors adversely affected the PIC's judgement in persisting with the approach as originally planned, despite the aircraft being higher, faster and closer to the aerodrome than was originally anticipated or was suitable for that type of approach. The stress and fatigue could also be expected to have adversely affected the PIC's attention and concentration during the approach, which probably contributed to the delayed descent from 6,500 ft, the PIC's lack of awareness of the autothrottle status, and the lack of monitoring of the flight instruments during the approach.

There was no indication from a review of the flight and duty records that the PIC would have been susceptible to fatigue from the design of the roster alone. The fatigue experienced by the PIC was related to both the stress he was under and a lack of sleep over a period of time in the lead up to, and including, the night before the occurrence. As this occurrence showed, pilots operating within flight and duty time limitations can still be subject to fatigue. In accordance with the fitness for flight crew duty proviso in the Civil Aviation Order 48 exemption, the responsibility for flight crew wellbeing rested with both the operator and their pilots.

Both flight crew members were experiencing a higher-than-normal workload as a consequence of the high, fast, and close approach, as well as the disconnection of the automatic flight system. Although the turbulence added to the workload by disturbing the aircraft from the intended flight path, those local conditions were expected and were common at Alice Springs. The primary outcome was that both pilots were focussed on tasks other than monitoring the aircraft's approach speed and profile.

The PIC's exposure to a significant period of single-pilot operations during the year prior to the incident had the potential to have adversely affected his ability to operate optimally in a multi-crew, high performance aircraft. However, it was not possible to establish if that recent non-airline experience influenced the pilot's actions on the day.

FINDINGS

From the evidence available, the following findings are made with respect to the stickshaker activation that occurred at Alice Springs, Northern Territory on 28 September 2008 and involved Boeing Company 717-200 aircraft, registered VH-NXE and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- The aircraft was higher, faster, and closer to Alice Springs Aerodrome than was suitable for the intended approach when the pilot in command began manoeuvring to intercept a 3 NM (6 km) final for runway 30.
- The pilot in command was unaware that the autothrottle was disengaged leading up to the time of the first stickshaker activation, contributing to an inadvertent decrease of airspeed below approach speed (Vapp).
- During the turn to intercept final approach, a combination of a 28° bank angle, a high rate of nose-up pitch change and airspeed below approach speed (Vapp) contributed to the activation of the stickshaker.
- The decrease in the margin between the reducing airspeed and the stickshaker speed depicted by the ‘red zipper’ and the pitch limit indicator on the primary flight displays was not detected by the flight crew prior to stickshaker activation.
- The pilot in command’s response to the first stickshaker activation did not include the application of heading hold or of maximum thrust as required by the relevant aircraft manufacturer procedure.
- The pilot in command’s judgement and monitoring ability was probably adversely influenced by stress and fatigue.

Other key findings

- The aircraft was stabilised by 400 ft above aerodrome elevation in accordance with the operator’s policy and procedures for stabilised approaches.
- Flight crew operating within regulatory flight and duty time limits can still be subject to fatigue.
- In accordance with the proviso for fitness for flight crew duty in the Civil Aviation Order 48 flight and duty time exemption, the responsibility for adequate flight crew well-being before flight rested with both the operator and their pilots.

SAFETY ACTION

The safety issues identified during this investigation are listed in the Findings and Safety Actions sections of this report. However, whereas an investigation may not identify any particular safety issues, relevant organisation(s) may proactively initiate safety action in order to reduce their safety risk.

All of the relevant organisations identified during this investigation were given a draft report and invited to provide submissions. Although no safety issues were identified during this investigation, the following proactive safety action was advised by the aircraft operator.

Aircraft operator

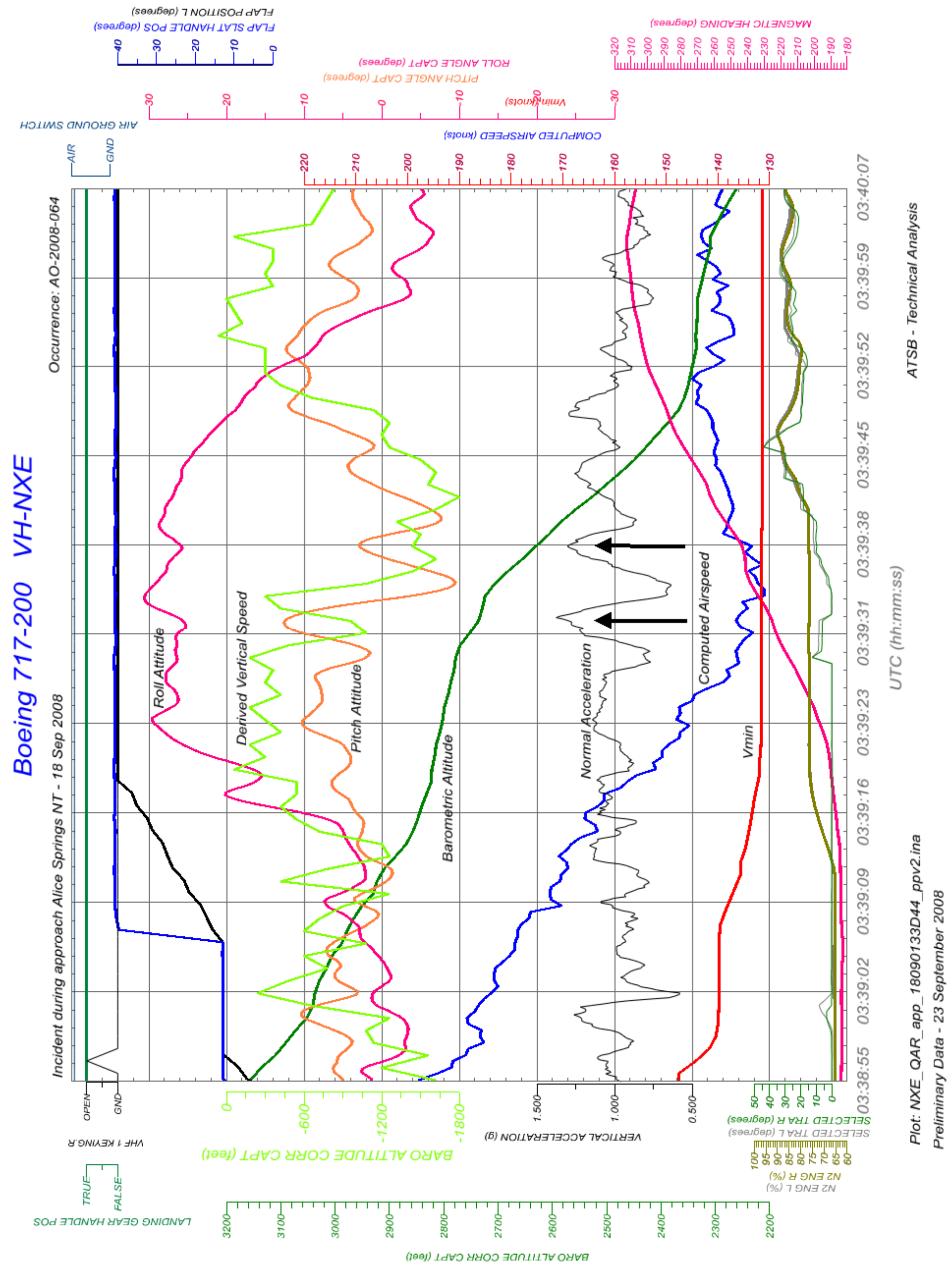
As a result of this occurrence, in February and March 2009, the aircraft operator proactively issued a number of notices to pilots. Those notices addressed the following topics:

- flight mode annunciator and automation mode awareness
- buffet protection and stickshaker events
- go-around policy
- 717 stall recovery.

In addition to the notices to pilots, the operator added a simulator session to their command upgrade training that included low speed handling and demonstration of stall protection system operation and introduced manual flight with autothrottles off on every recurrent sim exercise. Check pilots were briefed to check and reemphasise the requirement to monitor and annunciate the flight mode annunciator status.

The aircraft operator reported working with the aircraft manufacturer to better understand the 717 stall protection system and to effect change in order to avoid stickshaker events. Among a number of changes to the operator’s standard operating procedures was the modification of the recommended additives to reference approach speed (Vref) when on approach in forecast, anticipated or experienced turbulence.

APPENDIX A: DATA PLOT



APPENDIX B: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included:

- the flight crew of VH-NXE (NXE)
- the operator of NXE
- the aircraft manufacturer
- the Bureau of Meteorology
- Airservices Australia.

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 and operator of NXE, the aircraft manufacturer and the Civil Aviation Safety Authority (CASA).

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