Australian Government

Australian Transport Safety Bureau

ATSB TRANSPORT SAFETY REPORT
Aviation Occurrence Investigation
AO-2010-081
Final

Stickshaker activation Kalgoorlie Airport, Western Australia 13 October 2010 VH-NXD, Boeing 717-200

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Acknowledgements

Figure 1: Modified from original document, The Boeing Company

Abstract

On 13 October 2010, a Boeing 717-200 (717), registered VH-NXD, was being operated by Cobham Aviation Services Australia, on a scheduled passenger flight from Perth to Kalgoorlie, Western Australia. On board were 97 passengers, three cabin crew and two flight crew.

During the approach to land on runway 29 at Kalgoorlie Airport, the stickshaker activated. The copilot, who was the pilot flying, reduced the aircraft's pitch angle and continued the turn onto final. About a minute later, the approach was no longer stabilised and the flight crew conducted a go-around. On the second approach to land and after turning onto final, the copilot noted that the aircraft was below the required profile. As the copilot increased the aircraft's pitch attitude, the stickshaker activated for about 2 seconds. Following recovery actions, a go-around was conducted. The third approach was conducted by the pilot in command at an airspeed that was about 15 kts higher than the previous approaches.

The investigation found that the stickshaker activations were primarily a result of an incorrect approach speed. The approach speed generated by the flight management system (FMS) was based on a landing weight that was 9,415 kg less than the aircraft's actual weight. Prior to departure, the flight crew had inadvertently entered the aircraft's operating weight in lieu of the aircraft's zero fuel weight (ZFW) into the FMS. The data entry error also influenced the aircraft's take-off weight (TOW) in the FMS. The error went unnoticed and did not manifest as an operational problem until the approach into Kalgoorlie.

The investigation identified several organisational issues that had the potential to adversely affect the safety of future operations. Those issues related to the format of the aircraft load sheet, the verification check by the flight crew of the TOW against the load sheet and the lack of an independent validation check of the FMS-generated landing weight. In response, the operator has made a number of enhancements to the format of the 717 load sheet, the FMS weight data entry and verification procedures, the weight validation checks and the 717 simulator training in respect of recovery from stickshaker activation.

The application of correct operating data is a foundational and critical element of flight safety. In January 2011, the ATSB released a research report titled *Take-off performance calculation and entry errors: A global perspective.* It is available at http://www.atsb.gov.au/media/2229778/ar2009052.pdf.

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 appropriate, or to raise general awareness of important safety information in the industry. 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 13 October 2010, a Boeing 717-200 (717) aircraft, registered VH-NXD (NXD), was being operated by Cobham Aviation Services Australia on a scheduled passenger flight from Perth to Kalgoorlie, Western Australia. The flight was due to depart at 1150 Western Standard Time[1] with 97 passengers, three cabin crew and two flight crew onboard. The copilot was to be the pilot flying.

The flight crew began their pre-flight planning about an hour prior to the scheduled departure time. They noted that NXD was expected to be late in returning to Perth from the previous flight, but operations were hopeful of an on-time departure. After accessing the required weather and en route information, the flight crew attempted to complete the flight plan via the operator's computerised flight planning system. However, due to problems with the computer, the flight planning process had to be completed manually and the flight plan submitted via telephone.

After arriving at the aircraft, the flight crew began preparing the aircraft for the flight. Those preparations included obtaining the local weather conditions and calculating the regulated take-off weight (RTOW)[2].

About 3 minutes prior to departure, the passenger and baggage compartment loading information was received and printed via the communications addressing and reporting system (ACARS) onboard the aircraft. The pilot in command (PIC) read out the relevant information for the copilot to enter it into a hand-held computer (personal digital assistant or PDA) that calculated and printed the aircraft's load sheet. After verifying that the load sheet figures agreed with the ACARS printout figures, the PIC read out what he believed was the zero fuel weight (ZFW) from the load sheet. The copilot entered that figure into the flight management system (FMS) then enunciated the FMS-calculated take-off weight (TOW), which the PIC checked was below the RTOW calculations that were made earlier.

The PIC reported that the preparation of the aircraft and programming of the FMS were normal and not rushed. The aircraft was pushed back for departure 18 minutes after the scheduled departure time.

The flight crew reported that the departure and cruise phases of the flight were uneventful. In preparation for the approach and landing into Kalgoorlie, the flight crew reviewed the local weather conditions. That review indicated that the conditions were relatively benign with the wind favouring an approach to runway 29 and the FMS was programmed accordingly. Based on the aircraft's landing weight as derived from the ZFW and fuel load, the FMS calculated a landing reference speed (Vref[3]) of 116 kts. Given that the local weather conditions

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1 Western Standard Time (WST) was Coordinated Universal Time (UTC) + 8 hours.

2 The regulated take-off weight was the maximum weight permitted for takeoff based on the selected runway, local weather conditions and engine thrust setting.

3 Vref is the minimum speed at which a transport category aircraft complies with those handling criteria associated with approach and landing and is typically 1.3 times the aircraft's landing configuration stall speed.

were benign, the flight crew elected to use the default minimum additive of 5 kts, making the approach speed (Vapp)[4] 121 kts.

At about 1310, the flight crew joined the Kalgoorlie circuit with the autopilot and autothrottle engaged and proceeded to configure the aircraft for landing. By about 1312, the aircraft's landing gear and flaps were fully extended and the airspeed was reducing through about 160 kts.

The copilot recalled that, after commencing a turn to position the aircraft for landing, he 'didn't like the speed that the autothrottle was trying to command'. He 'was always holding the throttles high as the autothrottle system was unable to cope with the conditions'. The copilot stated that 'the pitch limit indicator[5] was bouncing down and the Red zipper[6] was bouncing up, constantly overriding the autothrottles'. Both the PIC and copilot perceived that the handling difficulties were due to turbulence. As the airspeed reduced towards 121 kts and due to his 'dislike of the situation', the copilot disengaged the autopilot. However, the autothrottles remained engaged 'as a backup'.

During the turn onto final approach, the aircraft's stickshaker[7] activated momentarily. The copilot responded by reducing the aircraft's pitch attitude while continuing the turn and the approach. The copilot reported that he had considered conducting an immediate go-around but continued the approach on advice from the PIC. About a minute later, the flight crew conducted a go-around as the approach no longer met the stabilised approach criteria.

The flight crew reported that for the second approach they added an additional 5 kts to the approach speed and limited the aircraft's bank angle to 20˚. The copilot recalled experiencing similar control difficulties while manoeuvring the aircraft for the second approach due to the perceived turbulence.

At about 1321 and after establishing the aircraft on final approach, the copilot noted that the aircraft was below the required approach path. As the copilot increased the aircraft's pitch attitude, the stickshaker activated for about 2 seconds. Following the necessary recovery actions, the approach was no longer stabilised and a go-around was conducted.

The third approach was conducted by the PIC at a reported approach speed of about 130 kts. After establishing the aircraft on a long final, the aircraft landed at 1328.

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4 Vapp is the approach target speed for a transport category aircraft and provides a speed margin over and above Vref based on the prevailing local environmental conditions.

5 The pitch limit indicator was located on the primary flight display and provided a graphically-displayed indication of the difference between the aircraft's angle of attack (airflow relative to the chord of the wing) and the stickshaker angle of attack.

6 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.

7 The stickshaker was a tactile warning felt through the control column that alerted the flight crew that the aircraft was near an aerodynamically-stalled condition of flight.

Personnel information

Pilot in command

The PIC held an Air Transport Pilot (Aeroplane) Licence (ATPL(A)) that was issued in 1985 and a 717 type rating that was issued in 2008. The PIC had a total of about 28,500 hours aeronautical experience, including about 1,500 hours on the 717.

Type training for the 717 was conducted by a third-party training provider in Australia during September and October 2008. It included ground and flight training that was conducted on a flight-training device and full flight simulator. The PIC's training records indicated satisfactory completion of stall recognition and recovery.

In December 2008, after a number of training flights, the PIC was cleared to line as a 717 captain.

The PIC held a valid Class 1 Aviation Medical Certificate that required reading glasses to be available while exercising the privileges of the licence.

The occurrence occurred on a Wednesday. In the preceding week, the PIC had the Saturday and Sunday free of duty. On Monday, the PIC signed on at 0507 for a return flight from Perth to Newman with a total flight time of 3 hours 22 minutes and a duty time of 4 hours 40 minutes. On Tuesday, the day before the occurrence, the PIC signed on at 0944 and completed a return flight from Perth to Adelaide via Kalgoorlie, before signing off at 1928. The total recorded flight time in that instance was 6 hours 56 minutes and duty time 9 hours 40 minutes. The PIC reported that although he was well rested for the flight, his roster had been subject to numerous changes that had made it difficult to manage his level of fatigue.

Copilot

The copilot held an ATPL(A) that was issued in 2007 and a 717 type rating that was issued in 2008. The copilot had a total of about 4,520 hours aeronautical experience, including about 1,800 hours on the 717.

The copilot's 717 training was conducted by a third-party training provider in Australia during April and May 2008. The copilot's training records indicated satisfactory completion of stall recognition and recovery.

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

The copilot held a valid Class 1 Aviation Medical Certificate with no restrictions.

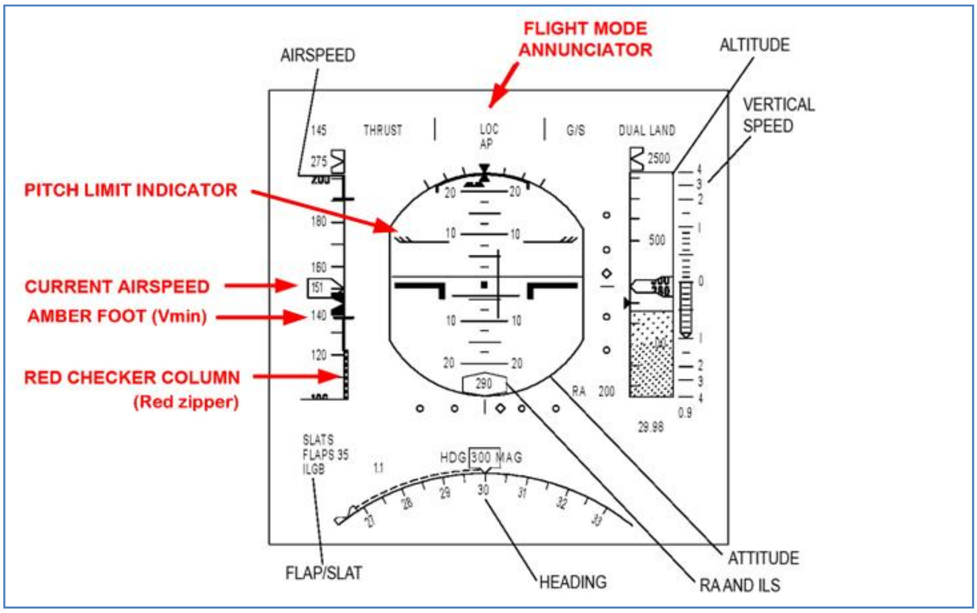
The copilot reported that he had had the week off prior to the occurrence for personal reasons and that he was not overworked. In addition, the copilot believed that although he didn't realise it on the day, his performance may have been influence by personal stressors.

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 1). 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 1: 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 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 (Red zipper) 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 was displayed throughout the flight. 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)[8] and red when the stickshaker activated.

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8 For the B717, Vmin is the minimum manoeuvring speed based on the aircraft's configuration and was the higher of 1.23 times the aircraft's stall speed and the 1.3g stickshaker speed.

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 flight control panel (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 (profile) switch on the FCP engaged FMS vertical profile guidance and activated the ATS.

At a speed not less than Vmin-5 kts 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

With FLAP 40 extended, Vref was equal to Vmin and was calculated by the FMS based on the aircraft zero fuel weight that was entered by the flight crew pre-flight. In this case, the recorded Vref/Vmin was 116 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. The aircraft manufacturer recommended that, depending on wind conditions, Vapp should be increased to either the greater of Vref+5 kts or Vref+wind additive (one-half of any steady state wind greater than 20 kts, or full gust, whichever was greater, up to a maximum of 20 kts). For the three approaches, the Vapp displayed on the PFD was the default speed of 121 kts.

Based on the aircraft’s actual weight at the time of the stickshaker activation, Vmin/Vref was 130 kts and the stall speed in straight and level flight (1g) was calculated to be 106 kts. Manoeuvres associated with positioning the aircraft during an approach or flying through turbulence generally increases the g-loading and, in turn, the stall speed. The g-loads that were recorded around the time of the stickshaker activations were in the order of 1.2g.

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 airspeed, 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.

A 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.

Meteorological information

The aerodrome forecast (TAF)[9] that was valid for arrival at Kalgoorlie predicted CAVOK[10] conditions. The wind was forecast to be from 270°(M) at 10 kts.

The 1300 METAR[11] for Kalgoorlie recorded CAVOK conditions, with a wind from 350°(M) at 8 kts and a temperature of 28 °C. The recorded observations made immediately before and after 1300 indicated similar conditions.

The TAF and area forecast predicted clear and stable conditions with light winds. There were no predictions of low-level turbulence.

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. The CVR was overwritten before the Australian Transport Safety Bureau (ATSB) accessed the data. The SSFDR and DAR data were provided to the ATSB for analysis.

The ATSB analysis included the verification of the data and the production of data listings, data plots (Appendixes A and B) and a sequence of events table (Appendix C).

The first stickshaker activation occurred at a height of 1,098 ft above ground level (AGL) as the aircraft was being manoeuvred onto final approach. The activation followed an increase in pitch angle from 10° to 14° and lasted for about 1 second. The recorded bank angle was 22° and the recorded airspeed was 124 kts at that time. The second stickshaker activation occurred during final approach at a height of 349 ft AGL and followed an increase in pitch angle from 9° to 14°. The

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9 Aerodrome forecasts are a statement of meteorological conditions expected for a specific period of time, in the airspace within a radius of 5 NM (9 km) of the aerodrome.

10 Ceiling and visibility OK, meaning that the visibility, cloud and present weather are better than prescribed conditions. For an aerodrome weather report, those conditions are visibility 10 km or more, no significant cloud below 5,000 ft or cumulonimbus cloud and no other significant weather within 9 km of the aerodrome.

11 Routine aerodrome weather report issued at fixed times, hourly or half-hourly.

activation lasted for about 2 seconds and the recorded airspeed was 122 kts. At the time of both activations, the aircraft was configured with gear down and flap 40° (landing flap). Both stickshaker activations were momentary and the aircraft was not aerodynamically stalled.

Based on the recorded data, the FMS-calculated TOW was 37,212 kg and the predicted LDW was 35,012 kg. At takeoff, the FMS-calculated TOW was 37,158 kg, reflecting the reduced fuel load following engine start and taxi. For landing, the FMS-calculated landing weight (LDW) was 34,527 kg and was a function of the entered ZFW and actual fuel remaining. However, in all cases the actual weight of the aircraft was 9,415 kg greater than the recorded weights.

Organisational and management information

Operator procedures

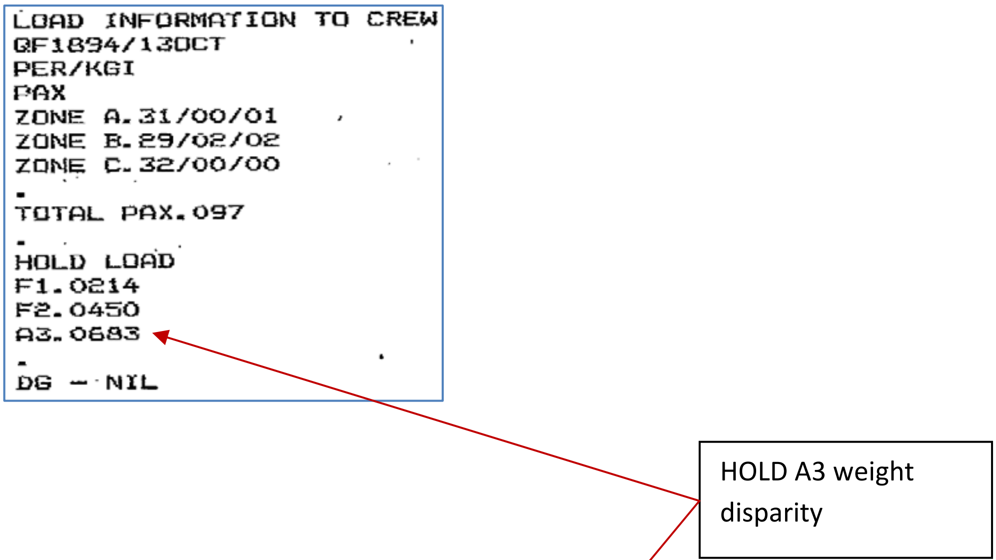
Load information

The operator's *B717 Aircraft Operating Procedures* described the procedures for entering load information into the PDA and FMS. Those procedures included that:

> Load information can be received by ACARS message, radio message or Load Information to Crew form.
>
> Upon arrival of the load information:
>
>> The captain is to call out the passenger zone details. After insertion, the FO will read out the total passenger count from the PDA.
>>
>> The Captain is to call out the baggage compartment details.
>>
>> The FO is to call out the Take-off weight from the PDA. From this the Captain will assess the planned RTOW calculations and revise the data if necessary.
>>
>> The FO will print the loadsheet and pass it to the Captain.
>>
>> If the RTOW calculations have been revised by the Captain, the FO is to cross-check the calculations.
>>
>> From either the ACARS screen/printout or Load Information To Crew form, the Captain will confirm the loadsheet values are correct, sign a copy of the loadsheet and pass it to the port despatch officer (together with a signed copy of the Dangerous Goods/Special Load NOTOC if applicable).
>>
>> The Captain will call out the ZFW. After insertion, the FO will call out the takeoff weight from the FMS, which is to be checked by the Captain against the loadsheet and the RTOW, announcing "RTOW checked" as confirmation that the takeoff weight is less than the RTOW calculation.

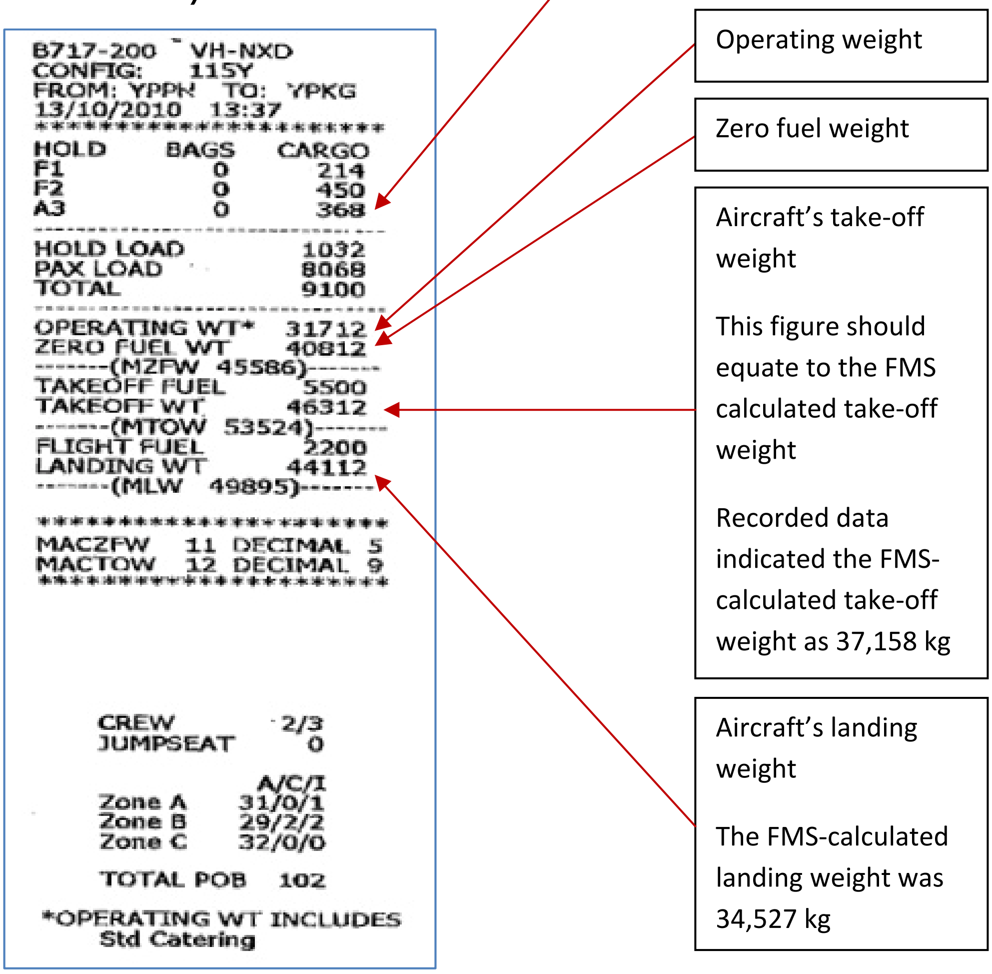
Load information for the flight was received via ACARS message (Figure 2). The ZFW that was to be entered into the FMS was located on the aircraft's load sheet (Figure 3).

Figure 2: Extract from the ACARS load information message



```
LOAD INFORMATION TO CREW
QF1894/13OCT
PER/KGI
PAX
ZONE A.31/00/01
ZONE B.29/02/02
ZONE C.32/00/00
-
TOTAL PAX.097
-
HOLD LOAD
F1.0214
F2.0450
A3.0683
-
DG - NIL
```


Figure 3: Extract from the aircraft's load sheet (as generated by the flight crew)



```
B717-200   VH-NXD
CONFIG:    115Y
FROM: YPPH   TO: YPKG
13/10/2010  13:37
**********************
HOLD       BAGS    CARGO
F1            0      214
F2            0      450
A3            0      368
----------------------------
HOLD LOAD           1032
PAX LOAD            8068
TOTAL               9100
----------------------------
OPERATING WT*      31712
ZERO FUEL WT       40812
-------(MZFW  45586)-------
TAKEOFF FUEL        5500
TAKEOFF WT         46312
-------(MTOW  53524)-------
FLIGHT FUEL         2200
LANDING WT         44112
-------(MLW   49895)-------

**********************
MACZFW   11 DECIMAL  5
MACTOW   12 DECIMAL  9
**********************

CREW              2/3
JUMPSEAT            0

               A/C/I
Zone A        31/0/1
Zone B        29/2/2
Zone C        32/0/0

TOTAL POB     102

*OPERATING WT INCLUDES
Std Catering
```

Stall recovery

The operator's *B717 Aircraft Operating Procedures* contained procedures to be followed as a result of stickshaker activation or stall recovery. Those procedures included that:

> **Stick Shaker operation during abnormal events or in Turbulence above 1000ft**
>
> There are several events that may result in activation of the Stick Shaker. Experience has shown that an engine failure at rotate may trigger a momentary Stick Shaker, and a PSEU failure during take off will result in a prolonged activation. Additionally momentary activation may occur in turbulent conditions.
>
> In any scenario, the prime consideration must be the adoption of a safe flight path. Adoption of a power setting, pitch attitude, aircraft configuration and terrain escape path to fly the aircraft out of the Stick Shaker envelope should be the prime consideration.
>
> **Recovery from Approach to Stall (Takeoff, Approach, Landing or Go-Around Configuration)**
>
> The procedure at FCOM PT 50.3 is to be followed.
>
> **NOTE:** IF ON APPROACH, THE STALL RECOVERY ACTIONS MUST BE FOLLOWED BY A MANDATORY GO-AROUND

Stabilised approaches

The operator's *B717 Aircraft Operating Procedures* also contained procedures relating to stabilised approaches. Those procedures included that an approach was considered stable provided it was maintained within certain parameters.

The parameters applicable to the Kalgoorlie approach were, airspeed between Vapp-5 and Vapp+10, on or within tolerance of the required approach slope, aircraft in the landing configuration, and a thrust setting appropriate to the aircraft configuration and local weather conditions. In addition, below 1,000 ft AGL, the maximum sustained rate of descent permitted was 1,000 ft/min.

In the event that the approach was not stable, or became destabilised below 1,000 ft AGL in IMC[12] or 500 ft in VMC[13], a go-around was to be carried out.

The flight crew reported that the go-arounds after the first and second approaches were initiated when the approaches no longer met the stabilised approach criteria.

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12 Instrument meteorological conditions (IMC) describes weather conditions that require pilots to fly primarily by reference to instruments, and therefore under instrument flight rules (IFR), rather than by outside visual references. Typically, this means flying in cloud or limited visibility.

13 Visual meteorological conditions is an aviation flight category in which visual flight rules (VFR) flight is permitted—that is, conditions in which pilots have sufficient visibility to fly the aircraft maintaining visual separation from terrain and other aircraft.

Aircraft manufacturer procedures

Stall recovery

The manufacturer's stall recovery procedures were contained in the Boeing 717 Flight Crew Operations Manual (FCOM) and stated:

> Procedures & Techniques – Recovery from Approach to Stall – Takeoff, Approach, Landing or Go-Around Configuration states:
>
> Note: If in a turn, PF calls "HEADING HOLD"
>
> **First Indication of Approach to Stall**
>
> APPLY MAXIMUM NORMAL THRUST. IF GROUND CONTACT IS IMMINENT, APPLY MAXIMUM N1 EMERGENCY THRUST
>
> ADJUST PITCH AS REQUIRED TO MINIMIZE ALTITUDE LOSS OR TO PROVIDE OBSTACLE CLEARANCE.
>
> MAINTAIN EXISTING FLAP/SLAT AND GEAR CONFIGURATION.
>
> WINGS LEVEL
>
> ACCELERATE TO MINIMUM MANEUVERING SPEED FOR EXISTING CONFIGURATION THEN ADJUST CONFIGURATION AS DESIRED

Additional information

Other 717 stickshaker occurrences

On 18 September 2008, the flight crew of a 717 aircraft, registered VH-NXE, experienced stickshaker activations during manoeuvring to land at Alice Springs Airport, Northern Territory. The aircraft was higher, faster and closer to the aerodrome than was suitable for the direct-to-final approach that was being attempted. 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 Vapp resulted in activation of the stickshaker system. The turn and approach were continued and a second activation of the stickshaker occurred a short time later. The flight crew were unaware that the autothrottle had earlier disengaged, contributing to the airspeed reduction below the approach speed.

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 Airport, Western Australia. The pilot flying had overshot the extended runway centreline and was applying a bank angle of 27° to regain the centreline prior to landing. The stickshaker activated when, during the turn, the pilot also increased the aircraft's pitch attitude to reduce the rate of descent. The event occurred at a height of 618 ft AGL and airspeed of 142 kts. The autothrottle was engaged throughout the approach and an increase in thrust was recorded at the same time as the stickshaker activated.

ANALYSIS

Introduction

During consecutive approaches to land, the aircraft’s stall warning system activated as the airspeed was reducing towards the final approach speed. The activations of the aircraft’s stick shaker indicated that it was being operated outside of its normal operational flight envelope and were a result of an incorrect approach reference speed.

The following analysis will examine the factors that led to the development of the event and the flight crew’s response to the stickshaker activations.

Stickshaker activations

The flight crew’s pre-landing preparations included the selection of an approach speed (Vapp) based on the flight management system (FMS) generated reference speed (Vref) of 116 kts and an additive to allow for local weather conditions. As the reported weather conditions were relatively benign, the flight crew accepted the FMS default approach speed of 121 kts (Vref+5 kts).

However, unbeknown to the flight crew, the required approach speed based on the aircraft’s weight was actually 135 kts. The effect was that the margin to the actual stall speed of 106 kts in straight and level flight was reduced from 29 kts to 15 kts. Similarly, the margin to stickshaker activation was reduced from 24 kts to just 10 kts. In addition, due to the predictive nature of the stall protection system, the margins were probably further reduced.

The slower-than-required approach speed led to a higher angle of attack and an increase in drag that had an adverse effect on the aircraft’s performance and flight control responsiveness. As a result, the engine power and pitch attitude required to maintain the desired flight profile were higher than usual and significant pitch oscillations were evident. Those pitch oscillations contributed to the difficulty experienced by the flight crew controlling the aircraft’s flightpath and maintaining a stabilised approach.

The flight crew was provided with an indication of the aircrafts proximity to the stickshaker activation speed by the relative positions of the pitch limit indicator (PLI) and the red checker column (Red zipper) on the primary flight display. Although the flight crew noted that the positions of the PLI and Red zipper were closer to stickshaker activation than was normal, they attributed those indications to the g-loading effects induced by turbulence. Those indications were symptomatic of an inappropriate approach speed and consistent with the degraded performance and controllability experienced by the flight crew.

Weight data calculation

The aircraft’s landing weight was calculated by the FMS based on the zero fuel weight (ZFW) and fuel load entered during pre-flight preparation. The data entry errors that were made pre-flight resulted in the calculated landing weight being

9,415 kg less than the aircraft's actual weight. As a result, the FMS-generated Vref was 15 kts less than the Vref appropriate to the actual weight of the aircraft.

At the time of the incident, the operator's procedures did not include a validation check of the landing weight. As such, there was the potential for a pre-departure data entry error to adversely affect the accuracy of the landing data. The absence of an independent method for validating the accuracy of the FMS-generated landing weight, resulted in a lack of assurance that the approach and landing speeds were valid.

Although the operator did not have a validation check of the landing weight, there were procedures in place to ensure that the take-off weight (TOW) was correct. If the TOW was correct, the landing weight based on the same ZFW figures and fuel load was likely to also be correct. In this case, the procedural check of the TOW was not effective in detecting the two data entry errors.

The first data entry error occurred during the transfer of baggage compartment weights from the electronically transmitted load information sheet to the hand-held computer. There was a check prescribed of the load sheet for accurate figures, but the PIC did not detect the error. That data entry error created a deficit of 315 kg in the ZFW, which was not in itself a significant disparity and did not have an influence on the occurrence.

The second data entry error occurred during the transfer of the ZFW from the load sheet print-out to the FMS. Instead of selecting the ZFW figure from the load sheet, the PIC selected the aircraft operating weight (essentially an empty aircraft) and read it out for the copilot to enter into the FMS. The FMS then added the fuel load to the ZFW to generate the TOW. When the copilot called out the FMS TOW for the PIC to validate, the proper response of 'RTOW checked' was probably made, but the significant disparity between the TOW calculated by the FMS and the actual TOW on the load sheet was not detected.

As a result of the undetected data entry errors, the FMS-calculated TOW was 9,415 kg less than the aircraft's actual TOW. Although that disparity had a significant effect on the required take-off speeds, due to aircraft design and the available runway length, the error went unnoticed at Perth and did not manifest as an operational problem until the approach into Kalgoorlie Airport.

Operational data assurance

The primary check of the weight data entered into the FMS was what the operator called the 'RTOW check'. Although checking that the FMS TOW was below the RTOW (regulated take-off weight) was important, the name and description of the check de-emphasised the other component of the check: the validation of the FMS TOW against the load sheet TOW. It is likely that over time, the full intent of the checklist item has been eroded such that it has diminished the effectiveness of the procedure.

At the time of the incident, the presentation of the various weights on the load sheet were such that the critical ZFW figure was located immediately below the aircraft's operating weight. Furthermore, both figures were presented in the same font. Although the figures were appropriately titled, their co-location and lack of differentiation increased the risk of an incorrect figure being selected and entered into the FMS.

The application of correct operating data is a foundational and critical element of flight safety. However, errors in the calculation, entry and checking of data are not uncommon in the airline operating environment.

In January 2011, the Australian Transport Safety Bureau (ATSB) released a research report titled *Take-off performance calculation and entry errors: A global perspective*. The report identified a number of error types and common contributing safety factors. The report also discussed several error capture systems that airlines and aircraft manufacturers could explore in an attempt to minimise the opportunities for take-off performance parameter errors from occurring, or to maximise the chance that any errors that do occur are detected and/or do not lead to negative consequences. The report is available at http://www.atsb.gov.au/media/2229778/ar2009052.pdf.

Pilot response to stickshaker activations

The flight crew reported that their response to the handling anomalies and first stickshaker were based on their assessment that they encountered turbulence while operating above 1,000 ft. Consequently, the turn and approach were continued. Eventually the approach became unstable and a go-around was completed.

On the second approach, the stickshaker occurred below 1,000 ft and with wings level. The flight crew reported that a missed approach was subsequently initiated because the approach was no longer stable.

However, the stall recovery procedure to be followed during an approach included applying maximum normal thrust, and rolling wings level. Furthermore, a stall recovery must then be followed by a mandatory go-around. Not following the prescribed stall recovery procedure increased the risk of the aircraft becoming aerodynamically stalled.

The flight crew's training records indicated that they had not received stall recovery training since completing their initial type endorsements in 2008. The operator's recurrent training programmes were designed to maintain and improve their pilot's competencies and skills. However, there was no recurrent training that addressed recovery from a stall or stickshaker activation.

Although stickshaker and stall recovery training was completed as part of the flight crews' initial endorsement, their ongoing competency was not assured.

FINDINGS

From the evidence available, the following findings are made with respect to the stickshaker activations that occurred at Kalgoorlie Airport, Western Australia on 13 October 2010 and involved Boeing 717-200 aircraft, registered VH-NXD and should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing safety factors

- During pre-flight preparation, the flight crew inadvertently entered a zero fuel weight (ZFW) figure into the flight management system that was 9,415 kg less than the actual ZFW.
- When conducting the pre-flight check of the take-off weight that was generated by the flight management system, the pilot in command did not include the necessary crosscheck against the load sheet, thereby missing an opportunity to identify the data entry error.
- The approach speed generated by the flight management system, based on the previously entered incorrect zero fuel weight, was 15 kts less than the appropriate approach speed.
- As a result of the incorrect approach speed, aircraft performance was adversely affected and stall margins reduced, leading to activation of the stickshaker on the first two approaches.
- The presentation on the aircraft load sheet of the zero fuel weight immediately below the operating weight increased the risk of flight crew selecting the inappropriate figure for flight management system data entry. *[Minor safety issue]*
- The operator's procedure for confirming the validity of the flight management system generated take-off weight did not place sufficient emphasis on the check against the load sheet. *[Minor safety issue]*
- The operator's procedures did not include a validation check of the landing weight generated by the flight management system, which resulted in a lack of assurance that the approach and landing speeds were valid. *[Minor safety issue]*

Other safety factors

- In response to the stickshaker activations, the flight crew did not follow the prescribed stall recovery procedure and did not perform an immediate go-around.
- The operator's recurrent training programs did not address the recovery from a stall or stickshaker activation such that the ongoing competency of their flight crew was not assured. *[Minor safety issue]*

SAFETY ACTION

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

All of the responsible organisations for the safety issues identified during this investigation were given a draft report and invited to provide submissions. As part of that process, each organisation was asked to communicate what safety actions, if any, they had carried out or were planning to carry out in relation to each safety issue relevant to their organisation.

Cobham Aviation Services Australia

Aircraft load sheet

Minor safety issue

The presentation on the aircraft load sheet of the zero fuel weight immediately below the operating weight increased the risk of selecting the inappropriate figure for flight management system data entry.

Action taken by Cobham Aviation Services Australia

As a result of this occurrence, the presentation of the load sheet has been changed to separate the operating weight and the zero fuel weight data in order minimise the risk of inadvertent selection of an incorrect weight.

Take-off weight validation

Minor safety issue

The operator's procedure for confirming the validity of the flight management system generated take-off weight did not place sufficient emphasis on the check against the load sheet.

Action taken by Cobham Aviation Services Australia

As a result of this occurrence, the Flight Management System (FMS) Weight Data Entry and Verification procedures were amended to confirm that that the FMS-computed take-off weight corresponded to that contained in the load sheet.

Landing weight validation

Minor safety issue

The operator's procedures did not include a validation check of the landing weight generated by the flight management system, which resulted in a lack of assurance that the approach and landing speeds were valid.

Action taken by Cobham Aviation Services Australia

A number of enhancements to procedures were introduced as a result of this occurrence. In the first place, prior to departure, the landing weight from the aircraft's load sheet is required to be entered onto the landing take-off and landing data (TOLD) card. Then, prior to establishing the approach speeds, the pilot monitoring is now required to call out the landing weight from the FMS, and the pilot flying will confirm this with the expected landing weight that is written on the TOLD card and call 'landing weight checked'.

Recurrent training

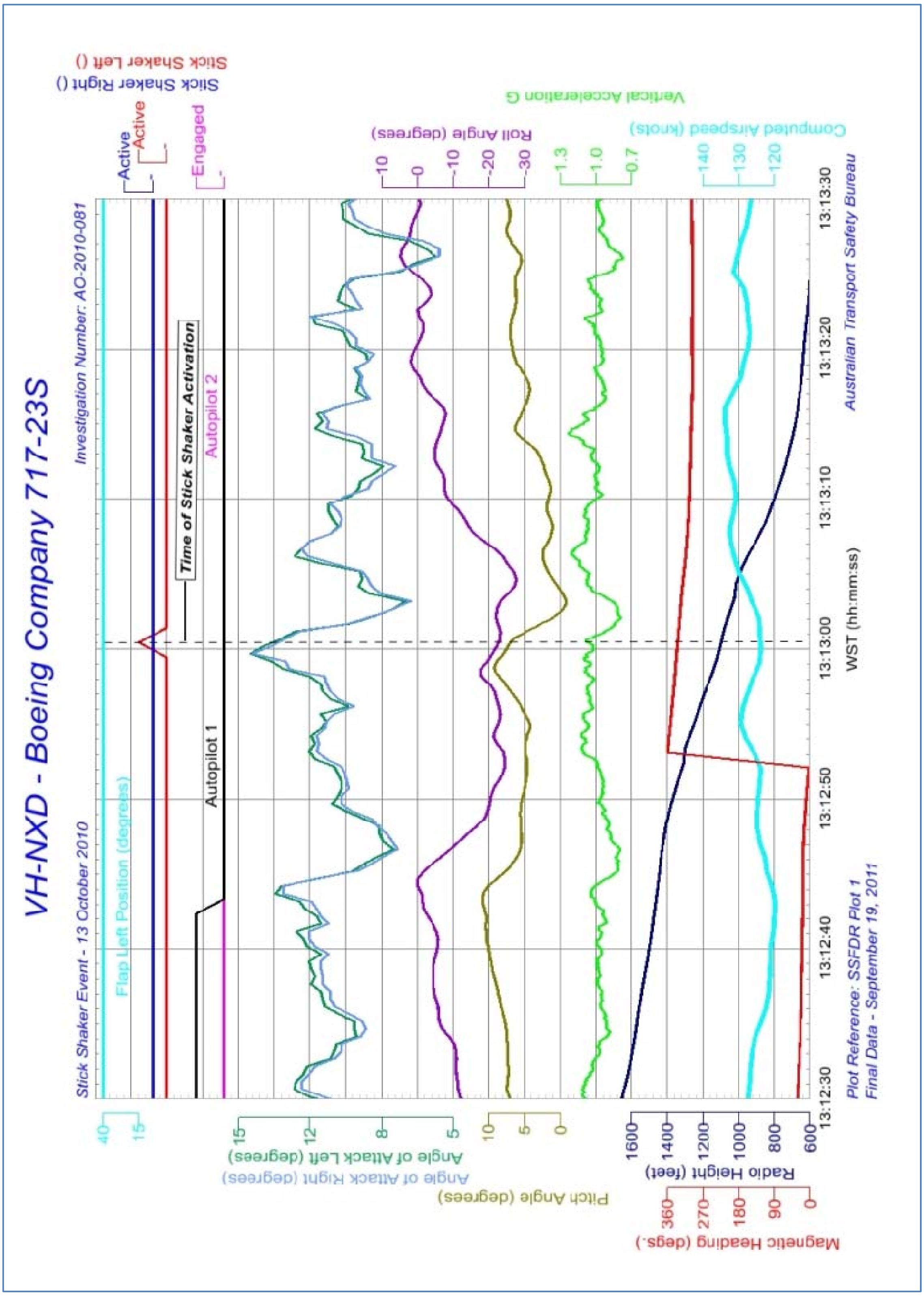
Minor safety issue

The operator's recurrent training programs did not address the recovery from a stall or stickshaker activation such that the ongoing competency of their flight crew was not assured.

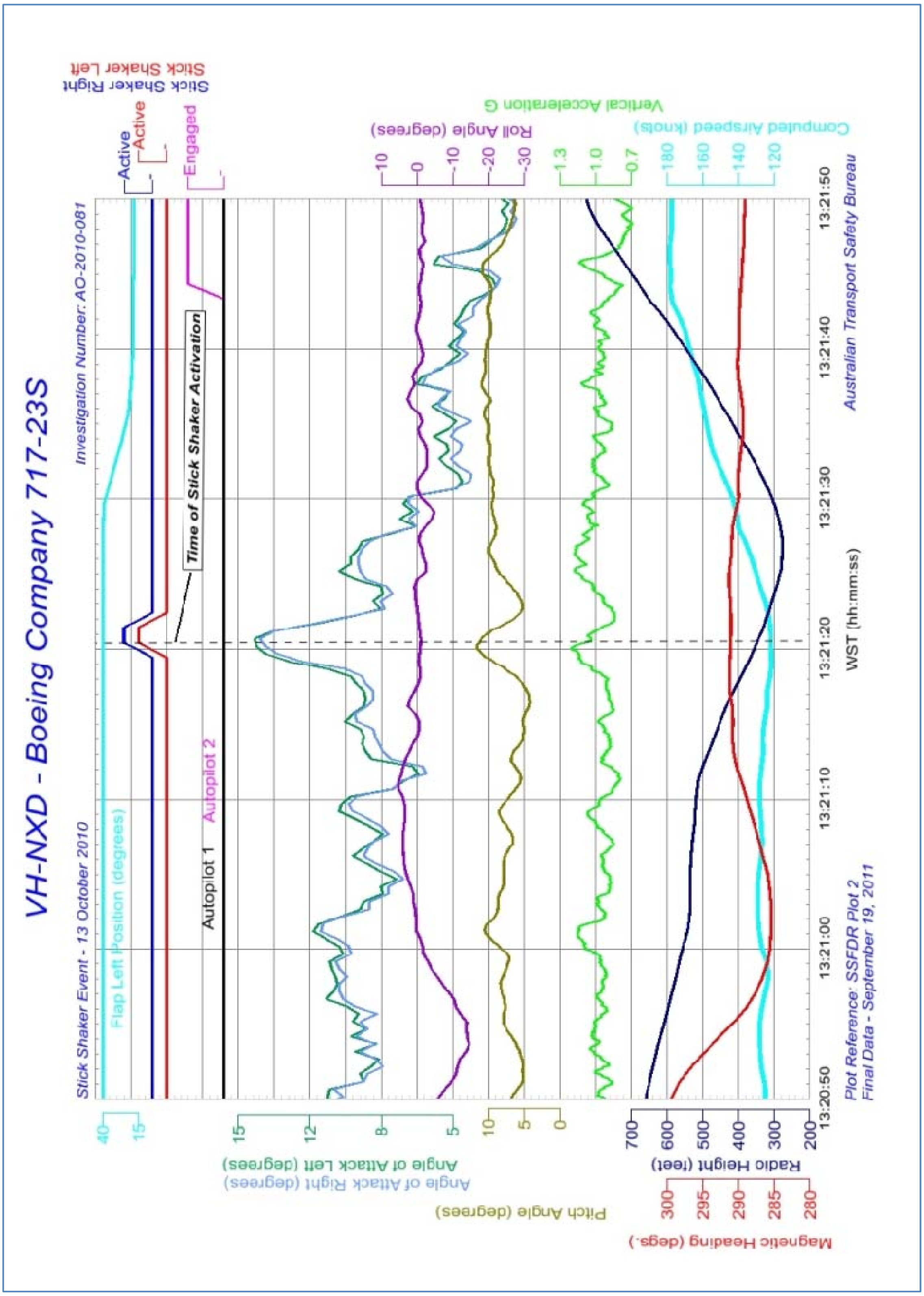
Action taken by Cobham Aviation Services Australia

Cobham Aviation Services Australia has advised that, as part of the simulator cycle that is being developed, a supporting detailed training syllabus will address stickshaker recovery actions.

APPENDIX A: DATA PLOT - 1st STICKSHAKER EVENT



APPENDIX B: DATA PLOT - 2nd STICKSHAKER EVENT



APPENDIX C: SEQUENCE OF EVENTS TABLE

Time (WST)	Event	CAS[14] (kts)
1223:37	Take-off roll commenced	N/A
1224:13	Takeoff from RWY 19 at Perth Airport - Pitch angle = 8.7°	143
1256:15	Top of descent.	275
1312:06	Flaps fully extended - Flaps angle = 40°	161
1312:57 – 1313:00	Angle of attack (AOA): Right increased from 9.8° to 14.4° Left increased from 9.6° to 14.3°	129 to 124
1313:01	Stickshaker Right activated for 1 second - Radio altitude = 1,099 ft - AOA Right = 13.8° - AOA Left = 13.4° - Pitch angle = 7.5° - Roll angle = -22.3° (left wing down)	124
1314:04	Go-around initiated	123
1321:12	Aircraft turned onto final approach for RWY 29 at Kalgoorlie Airport	128
1321:21	Stickshaker Left and Right became active for two seconds - Radio altitude = 349 ft - AOA Right = 14.2° (increased from 9.1° at 1321:18) - AOA Left = 14.0° (increased from 8.7° at 1321:18) - Pitch angle = 11.6°	122
1321:25	Go-around initiated	128
1328:09	Touchdown at Kalgoorlie on RWY 29	134

[14] Computed airspeed rounded to the nearest knot.

APPENDIX D: SOURCES AND SUBMISSIONS

Sources of Information

The sources of information during the investigation included the:

- flight crew of VH-NXD (NXD)
- operator of NXD
- aircraft manufacturer
- Bureau of Meteorology.

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 NXD, the aircraft manufacturer, the National Transport Safety Bureau (NTSB) and the Civil Aviation Safety Authority (CASA).

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

Stickshaker activation – Kalgoorlie Airport, Western Australia,
13 October 2010 , VH-NXD, Boeing 717-200