Australian Government

Australian Transport Safety Bureau

Operational event involving a Boeing 737, VH-VUZ

Near Launceston, Tasmania, 4 January 2013

ATSB Transport Safety Report

Aviation Occurrence Investigation

AO-2013-041

Final – 26 May 2014

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

Publishing information

Published by: Australian Transport Safety Bureau
Postal address: PO Box 967, Civic Square ACT 2608
Office: 62 Northbourne Avenue Canberra, Australian Capital Territory 2601
Telephone: 1800 020 616, from overseas +61 2 6257 4150 (24 hours)
Accident and incident notification: 1800 011 034 (24 hours)
Facsimile: 02 6247 3117, from overseas +61 2 6247 3117
Email: atsbinfo@atsb.gov.au
Internet: www.atsb.gov.au

Addendum

Page	Change	Date

Operational event involving a Boeing 737, VH-VUZ

What happened

Soon after 0600 Eastern Daylight-saving Time[1] on 4 January 2013, a Boeing 737-800, registered VH-VUZ, departed Launceston, Tasmania for Melbourne, Victoria. The flight was a scheduled passenger service, with a planned flight time of 48 minutes. The first officer (FO) was the pilot flying (PF).

During the departure, as the aircraft climbed through about 3,900 ft, the FO selected level change (LVL CHG) as the vertical auto-flight mode and an airspeed of 250 kt, with the intention of later selecting vertical navigation (VNAV) mode. During the investigation, both crew commented that VNAV mode is normally selected to manage aircraft airspeed and vertical profile during departure, but on this occasion the FO elected to use LVL CHG mode. The FO could not recall why LVL CHG mode was used on this occasion, but the captain recalled that it was probably used to expedite climb through a layer of cloud and/or turbulence. Both crew members overlooked the intended subsequent selection of VNAV mode, so the aircraft continued to climb in LVL CHG mode at a constant 250 kt. The characteristics of each relevant vertical auto-flight mode are outlined later in the report.

As the aircraft climbed at a constant airspeed, the aircraft Mach number[2] was steadily increasing. Passing about flight level (FL)[3] 260, the auto-flight system sequenced automatically from climb at a constant airspeed of 250 kt, to climb at a constant Mach 0.62, which was the Mach number corresponding to 250 kt at the point that the changeover occurred. As the aircraft then continued to climb at a constant Mach 0.62, the airspeed slowly reduced.[4] The changeover from a constant airspeed to a constant Mach number during the climb went unnoticed by the crew, as did the gradually reducing airspeed as climb continued beyond the changeover altitude.

Approaching FL 350, about 20 minutes after departure, the FO noticed a 'buffet alert' caution appear in the scratchpad of the control display unit (CDU).[5] At about the same time, the captain recalled that the aircraft auto-flight system made a small but noticeable pitch attitude reduction. Both pilots immediately directed their attention to the primary flight display and noticed that airspeed had reduced to the point that it was near the top of the amber bar on the airspeed indicator. The top of the amber bar represents the aircraft minimum manoeuvre airspeed (described in detail later in the report).

In responding to the low airspeed condition and attempting to accelerate, the crew reduced the aircraft pitch attitude to the point that the aircraft entered a shallow descent. Soon after, the crew was able to establish an accelerated climb to the intended cruising level.

---

1 Eastern Daylight-saving Time (EDT) was Coordinated Universal Time (UTC) + 11 hours.

2 Mach number is the ratio of true airspeed to the speed of sound in the surrounding air.

3 At altitudes above 10,000 ft in Australia, an aircraft's height above mean sea level is referred to as a flight level (FL). FL 260 equates to 26,000 ft.

4 The relationship between Mach number and airspeed is temperature dependent. In this case, as the aircraft climbed at a constant Mach number and temperature decreased, airspeed also decreased.

5 Two identical CDUs (one available to each pilot) are used by flight crew to enter data and control the flight management computer, and display flight management computer data and messages. The scratchpad refers to the bottom line of the CDU screen, used among other things to display a range of flight management computer advisory messages. One such advisory message is 'buffet alert'. When an advisory message appears, a message light on both CDUs also illuminates, to draw the crew's attention to the message. The operator's Flight Crew Operations Manual states that the 'buffet alert' message informs the crew that the aircraft manoeuvre margin is 'less than specified'.

Recorded data indicates that the aircraft reached a minimum airspeed of 201 kt computed airspeed[6] which was about 6 kt below the minimum manoeuvre airspeed at that moment.

Relevant auto-flight modes

The B737 auto-flight system consists of an auto-pilot flight director system (AFDS) and the auto-throttle system. The AFDS and auto-throttles are controlled using the mode control panel (MCP) and the flight management computer (FMC).[7] Crew inputs to the FMC are made using one of the two CDUs. The auto-flight system operates in various vertical modes according to the phase of flight, operating environment and crew requirements. Two commonly used vertical modes relevant to this occurrence are VNAV mode and LVL CHG mode.

VNAV mode

In VNAV mode the auto-flight system guides the aircraft along FMC-computed vertical profile selected by the crew on the CDU. During normal operations when economy climb speed schedule is selected,[8] the FMC airspeed profile holds the airspeed at 250 kt up to 10,000 ft (normal procedural requirement in Australian airspace) followed by acceleration to the FMC-computed economy climb airspeed. As climb continues at a constant airspeed, Mach number increases given a falling outside air temperature.[9] Climb normally continues at the economy-optimised climb airspeed until the Mach number reaches the FMC-computed economy-optimised Mach number. Climb then continues at the economy-optimised Mach number to the planned cruise altitude. Other climb speed modes selectable on the CDU include maximum angle climb and maximum rate climb.[10]

Recorded data indicates that during this occurrence had the crew climbed in VNAV mode and selected the economy climb speed schedule, the aircraft would have maintained 250 kt to 10,000 ft before accelerating to about 290 kt. The aircraft would have climbed at about 290 kt to almost FL 300, from which point climb would have continued at a constant Mach 0.75 to the planned cruising altitude of FL 360.

VNAV mode is selected by pressing the VNAV pushbutton on the MCP (Figure 1). When selected, a green bar on the VNAV pushbutton illuminates. During a climb in VNAV mode, the flight mode annunciator (FMA)[11] indication at the top of each pilot's primary flight display indicates N1[12] as the auto-throttle mode and VNAV SPD (speed) as the vertical auto-flight mode (Figure 2).[13] During a climb in VNAV mode, the indicated airspeed/Mach number (IAS/MACH) window on the MCP is blank, while the FMC target speed is displayed on the primary flight display airspeed indicator.

---

6 Computed airspeed referred to in this report is the same as the airspeed displayed on the captain's airspeed indicator, and referred to in the Flight Crew Operations Manual as calibrated airspeed. Calibrated airspeed accounts for airspeed indication system errors.

7 The FMC performs a range of navigation and performance-related functions based upon crew-entered data, aircraft system data, and navigational and performance databases. The FMC provides auto-flight and auto-throttle guidance and control.

8 The economy climb speed schedule is computed by the FMC to minimise operating costs. The speed schedule is based upon a cost index entered by the crew and other performance-related parameters.

9 In the standard atmosphere, temperature decreases with altitude at a rate of 1.98^{o} C per 1,000 ft, up to the tropopause (36, 089 ft in the standard atmosphere).

10 Maximum angle climb can be used for obstacle clearance purposes, or to reach a required altitude over minimum distance. Maximum rate climb can be used when a high rate of climb is required, and to minimise the time required to climb to the planned cruise altitude.

11 Auto-flight modes are displayed on the FMA at the top of each pilot's primary flight display. Engaged modes are displayed at the top of the FMA in green letters. Armed modes are displayed in smaller white letters beneath the engaged modes. The mode annunciations, from left to right, are auto-throttle, roll (or lateral) mode, and pitch (or vertical) mode.

12 N1 auto-throttle mode engages automatically when LVL CHG or VNAV modes are engaged during climb. The auto-throttles then maintain engine speed at the N1 limit selected on the CDU.

13 Note that VNAV SPD will change to VNAV PTH (path) and N1 will change to FMC SPD during a level segment of a VNAV climb.

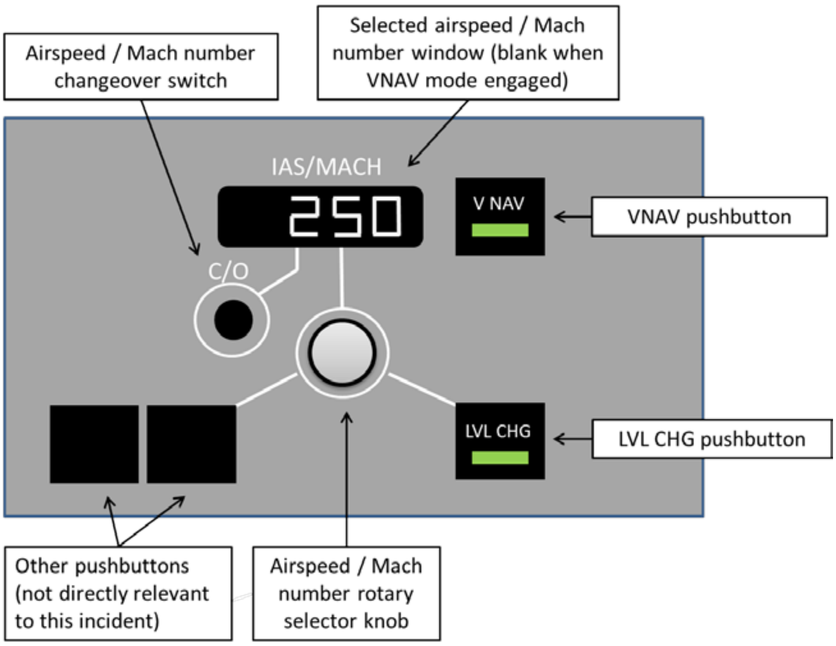
LVL CHG mode

In LVL CHG mode, the auto-flight system guides the aircraft vertically at the airspeed selected by the crew on the MCP. LVL CHG mode is sometimes used during a climb to allow a more active and typically short-term approach to vertical profile management. For example, rather than allowing the aircraft to accelerate in VNAV mode in accordance with the FMC-computed speed profile, the crew may elect to temporarily retard acceleration or reduce airspeed using LVL CHG mode. Temporarily retarding acceleration or reducing speed may generate a higher short-term rate of climb, thereby facilitating an expedited climb through a layer of cloud or turbulence.

LVL CHG mode is selected by pressing the LVL CHG pushbutton on the MCP (Figure 1). As with the VNAV pushbutton, a green bar illuminates on the pushbutton when LVL CHG is selected. The airspeed control knob on the MCP is then used to select the required climb airspeed or Mach number, which is displayed in the corresponding IAS/MACH window. The changeover (C/O) switch on the MCP is pushed to cycle the IAS/MACH display between indicated airspeed and Mach number. During this occurrence, the switch from indicated airspeed (250 kts) to Mach number (Mach 0.62) occurred automatically at about FL 260 as the aircraft climbed.

When LVG CHG mode is selected, the FMA indicates N1 as the auto-throttle mode and MCP SPD (speed) as the vertical auto-flight mode (Figure 2).

Figure 1: Representation of relevant part of MCP



Source: ATSB

Figure 2: Representation of the FMA during climb in VNAV and LVL CHG modes

Example of FMA annunciations during a climb in VNAV mode. In this case, VNAV SPD indicates that the auto-flight system is following the FMC-computed speed profile. N1 indicates that the auto-throttle system is commanding a set engine speed limit and LNAV (lateral navigation) indicates that the auto-flight system is following a programmed lateral track.

Example of FMA annunciations during a climb in LVL CHG mode. In this case, MCP SPD indicates that the auto-flight system is in LVL CHG mode maintaining the speed set on the MCP. As above, N1 indicates that the auto-throttle system is commanding a set engine speed limit and LNAV indicates that the auto-flight system is following a programmed lateral track .

Source: ATSB

Minimum manoeuvre airspeed

The minimum manoeuvre airspeed is represented as the top of an amber bar on the primary flight display airspeed indicator. Minimum manoeuvre speed is defined in the operator's Flight Crew Operations Manual (FCOM) as the airspeed that provides:

- 1.3g[14] manoeuvre capability to the stick shaker below approximately 20,000 ft.
- 1.3g manoeuvre capability to the low airspeed buffet (or the approved manoeuvre capability entered into the Flight Management Computer maintenance pages) above approximately 20,000 ft.[15]

The FCOM adds the following caution:

> Reduced maneuver [*sic*] capability exists when operating within the amber regions below the minimum maneuver [*sic*] airspeed or above the maximum maneuver [*sic*] airspeed. During non-normal conditions the target airspeed may be below the minimum maneuver [*sic*] airspeed.

System alerts and levels of protection reduce the likelihood of continued unintended deceleration below minimum manoeuvre airspeed. During this occurrence, the crew responded to the 'buffet alert' message on the CDU scratchpad and a small auto-flight system pitch attitude reduction, which were the first indications that effectively captured the attention of the crew. Had the airspeed

---

[14] 1.3g represents 1.3 times the force of gravity. In this context, 1.3g means that the aircraft can be manoeuvred at up to 1.3g without activating the stick shaker or generating a low airspeed buffet. Approximately 1.3g will be experienced during a level turn at 40 degrees angle of bank.

[15] The operator involved in this occurrence used manufacturer FMC settings with respect to the low airspeed buffet manoeuvre margin.

continued to reduce, other more salient alerts would have been triggered. For example, under the existing conditions, an 'airspeed low, airspeed low' voice alert would have been triggered at about 194 kt, and the stick-shaker[16] would have activated at about 162 kt.

Crew comments

The crew commented that the effectiveness of their instrument scan and auto-flight system mode awareness was probably compromised to some degree by the distractions sometimes associated with relatively short sectors. While the aircraft was climbing, each pilot consumed a meal before commencing preparations for their arrival into Melbourne. While the crew were broadly scanning aircraft instruments throughout the climb, nothing specifically drew their attention to the unintended auto-flight climb mode or the gradually reducing airspeed (beyond the changeover altitude). The crew commented that the occurrence provided a salient reminder regarding the importance of maintaining auto-flight system mode awareness.

ATSB comment

The ATSB commends the flight crew and operator for submitting a report in relation to this occurrence, noting that the occurrence was not reportable under the definitions provided in *Transport Safety Investigation Regulations 2003*. The report was submitted in the interest of aviation safety and to provide an opportunity for others to learn from the occurrence.

When auto-flight system mode awareness is compromised, continued operation in an unintended mode is sometimes the result. Such scenarios often lead to unintentional non-compliance with operational or procedural requirements. Other recent occurrences investigated by the ATSB with similarities to this occurrence include:

- ***AO-2012-040 Descent below minimum safe altitude involving Boeing 737-476, VH-TJS, 21 km south of Canberra Airport, ACT, 12 February 2012.*** The ATSB found that at the time of the occurrence the auto-flight system was in LVL CHG mode rather than the VNAV mode (specified by the operator for the phase of the approach being flown). Engagement of LVL CHG mode resulted in descent through minimum safe altitude to the altitude selected by the crew on the MCP. While this occurrence relates to altitude management rather than speed profile management, the lessons with respect to auto-flight system mode awareness are similar. A copy of the ATSB report dealing with this occurrence can be found on the ATSB website at www.atsb.gov.au/publications/investigation_reports/2012/aair/ao-2012-040.aspx
- ***AO-2012-103 Descent below segment minimum safe altitudes involving Airbus A320-232, VH-VQA, near Queenstown, New Zealand, 16 July 2012.*** In this occurrence, the ATSB found that the crew intended to switch auto-flight system modes during descent, but inadvertently overlooked that selection. As a result, descent continued in an unintended mode that did not prevent infringement of procedure altitude constraints. This occurrence highlighted the importance of attention to active and armed auto-flight system modes. A copy of the ATSB report dealing with this occurrence can also be found on the ATSB website at www.atsb.gov.au/publications/investigation_reports/2012/aair/ao-2012-103.aspx

Since the introduction of highly automated aircraft auto-flight systems, numerous studies have examined the effectiveness of the human-machine interface and the role of flight crew in manipulating and monitoring these systems. Reports associated with such studies of relevance to this occurrence include the following:

- A 1996 report by the Federal Aviation Administration (FAA) Human Factors Team looked at the interface between flight crew and highly automated auto-flight systems. While avionics technology may have advanced since the report was prepared, many issues addressed in the

[16] The stick shaker is a device that physically shakes the control column (through a small angle in the fore and aft plane) providing artificial warning of an approaching aerodynamic stall.

report remain highly relevant. The report devotes considerable attention to flight crew situation awareness, including the issues surrounding auto-flight system mode and aircraft energy state awareness. This report can be accessed on the FAA website at www.faa.gov/aircraft/air_cert/design_approvals/csta/publications

- A recent report by the FAA Performance-based operations Aviation Rulemaking Committee Flight Deck Automation Working Group titled *Operational Use of Flight Path Management Systems* addresses the safety and efficiency of modern flight deck systems for flight path management (including energy-state management). Among other things, the report recommends better training and flight crew procedures to improve auto-flight system mode awareness '… as part of an emphasis on flight path management.' This report can be accessed on the FAA website at www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/parc/parc_reco/
- In 2010, the European Aviation Safety Agency (EASA) issued Safety Information Bulletin 2010-33 *Flight Deck Automation Policy – Mode Awareness and Energy State Management* to '… remind air operators of the importance of air crews continuing to be aware of the automation mode under which the aircraft is operating ...' The bulletin also comments:

  > Critically, in complex and highly automated aircraft, flight crews can lose situational awareness of the automation mode under which the aircraft is operating … lead to the mismanagement of the energy state of the aircraft or to the aircraft deviating from the intended flight path.

  This bulletin can be accessed on the EASA website at http://ad.easa.europa.eu/ad/2010-33.

Safety action

Whether or not the ATSB identifies safety issues in the course of an investigation, relevant organisations may proactively initiate safety action in order to reduce their safety risk. The ATSB has been advised of the following proactive safety action in response to this occurrence.

Operator

Since this occurrence, the operator has introduced a policy requiring that FMA changes be announced by the PF (with some exceptions), and that the pilot monitoring should announce any FMA changes missed by the PF. While this action may not directly address the possibility of continued operation in an unintended mode, it is likely to have a positive impact on overall flight mode awareness, and lead to improved crew communication with respect to the status of the auto-flight system. The operator also included auto-flight system mode awareness as a briefing item during a subsequent recurrent training program during 2013, to further highlight the importance of mode awareness to all flight crew.

Safety message

This occurrence highlights the importance of consistent attention to auto-flight system modes and aircraft energy state. Operation of the auto-flight system in an unintended or inappropriate mode can lead to an undesirable energy state, or in other cases, unintended operational or procedural non-compliance.

General details

Occurrence details

Date and time:	04 January 2013 – 0620 EDT	
Occurrence category:	Incident	
Primary occurrence type:	Aircraft control	
Location:	142 km north west of Launceston Airport, Tasmania	
	Latitude: 40° 21.9’ S	Longitude: 146° 34.8’ E

Aircraft details

Manufacturer and model:	Boeing Company 737-8FE	
Registration:	VH-VUZ	
Operator:	Virgin Australia	
Serial number:	39921	
Type of operation:	Air transport – high capacity	
Persons on board:	Crew – Unknown	Passengers – Unknown
Injuries:	Crew – Nil	Passengers – Nil
Damage:	None	

About the ATSB

The Australian Transport Safety Bureau (ATSB) is an independent Commonwealth Government statutory agency. The ATSB is governed by a Commission and is entirely separate from transport regulators, policy makers and service providers. The ATSB's function is to improve safety and public confidence in the aviation, marine and rail modes of transport through excellence in: independent investigation of transport accidents and other safety occurrences; safety data recording, analysis and research; and 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.

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.

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.

About this report

Decisions regarding whether to conduct an investigation, and the scope of an investigation, are based on many factors, including the level of safety benefit likely to be obtained from an investigation. For this occurrence, a limited-scope, fact-gathering investigation was conducted in order to produce a short summary report, and allow for greater industry awareness of potential safety issues and possible safety actions.