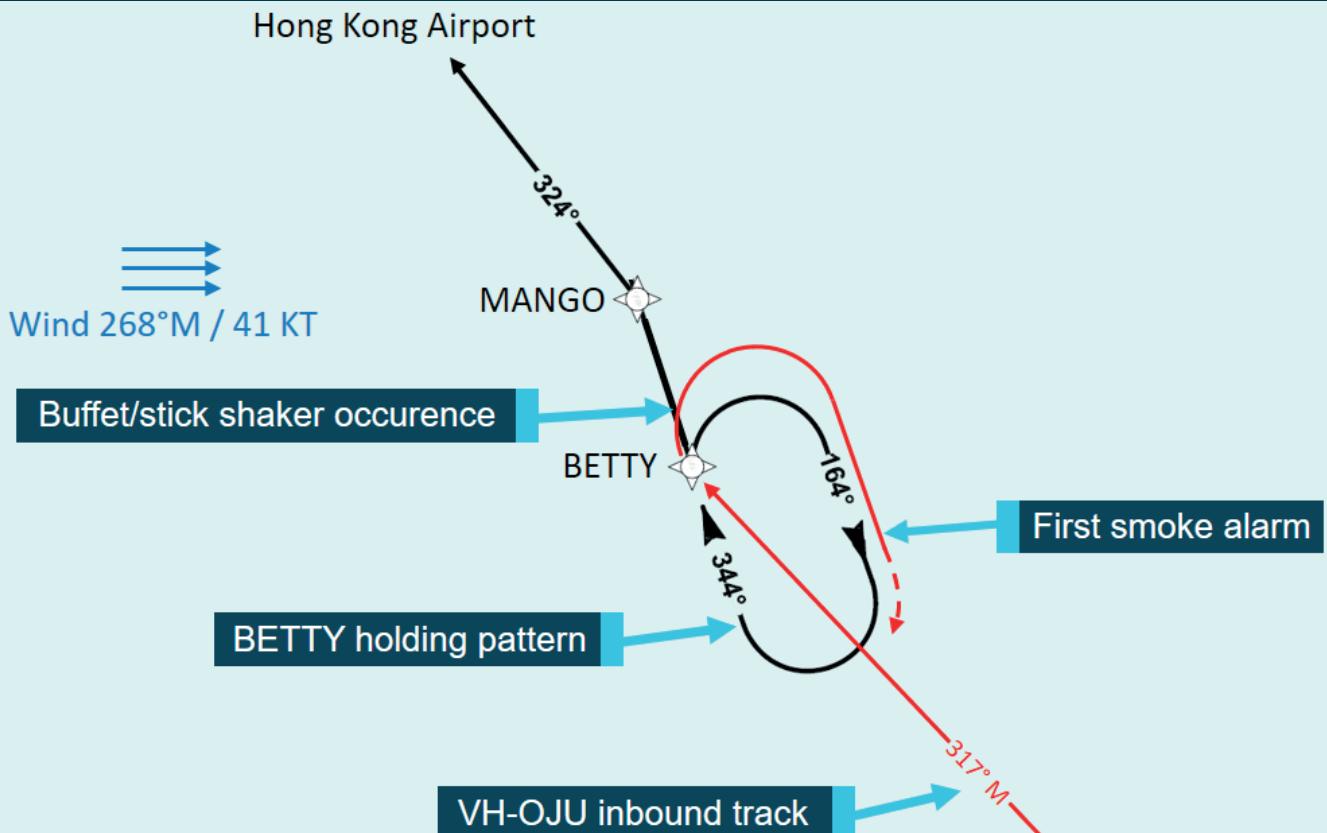




In-flight upset involving Boeing 747-438, VH-OJU

110 km SE of Hong Kong Airport | 7 April 2017



Investigation

ATSB Transport Safety Report

Aviation Occurrence Investigation

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Addendum

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Safety summary

What happened

On 7 April 2017, a Qantas Airways Boeing 747-438, registered VH-OJU, was operated as scheduled passenger flight QF29 from Melbourne, Victoria, to Hong Kong International Airport, in the Hong Kong Special Administrative Region of the People's Republic of China. On board were 17 crew and 347 passengers.

While descending toward Hong Kong International Airport, air traffic control instructed the flight crew to hold at waypoint BETTY.

When entering the holding pattern, the aircraft's aerodynamic stall warning stick shaker activated a number of times and the aircraft experienced multiple oscillations of pitch angle and vertical acceleration. During the upset, passengers and cabin crewmembers struck the cabin ceiling and furnishings.

A lavatory smoke alarm later activated, however, the cabin crew determined the smoke alarm to be false and silenced the alarm. The aircraft landed at Hong Kong International Airport without further incident. Four cabin crewmembers and two passengers suffered minor injuries during the incident and the aircraft cabin sustained minor damage.

What the ATSB found

The ATSB found that while planning for the descent, the flight crew overwrote the flight management computer provided hold speed. After receiving a higher than expected hold level, the flight crew did not identify the need to re-evaluate the hold speed. This was likely because they were not aware of a need to do so, nor were they aware that there was a higher hold speed requirement above FL 200. Prior to entering the hold, the speed reduced below both the selected and minimum manoeuvring speeds. The crew did not identify the low speed as their focus was on other operational matters.

The ATSB also found that due to a desire to remain within the holding pattern and a concern regarding the pitch up moment of a large engine power increase, the pilot flying attempted to arrest the rate of descent prior to completing the approach to stall actions. In addition, the pilot monitoring did not identify and call out the incomplete actions. This resulted in further stall warning stick shaker activations and pilot induced oscillations that resulted in minor injuries to cabin crewmembers and passengers.

Additionally, the operator provided limited guidance for hold speed calculation and stall recovery techniques at high altitudes or with engine power above idle. This in turn limited the ability of crew to retain the necessary manual handling skills for the recovery.

What's been done

In response to the occurrence, the operator updated flight crew training lesson plans and commenced retraining of flight crew in more complex stall recovery events. The operator also amended the Boeing 747-400, 787 and 737 flight crew training manuals and updated flight crew ground school lesson plans to ensure standardisation of training.

Safety message

Balancing competing attention or decision demands can interrupt trained flight crew responses leading to procedures not being completed in full, particularly so if flight crews are not receiving comprehensive and regular training in the application of these skills.

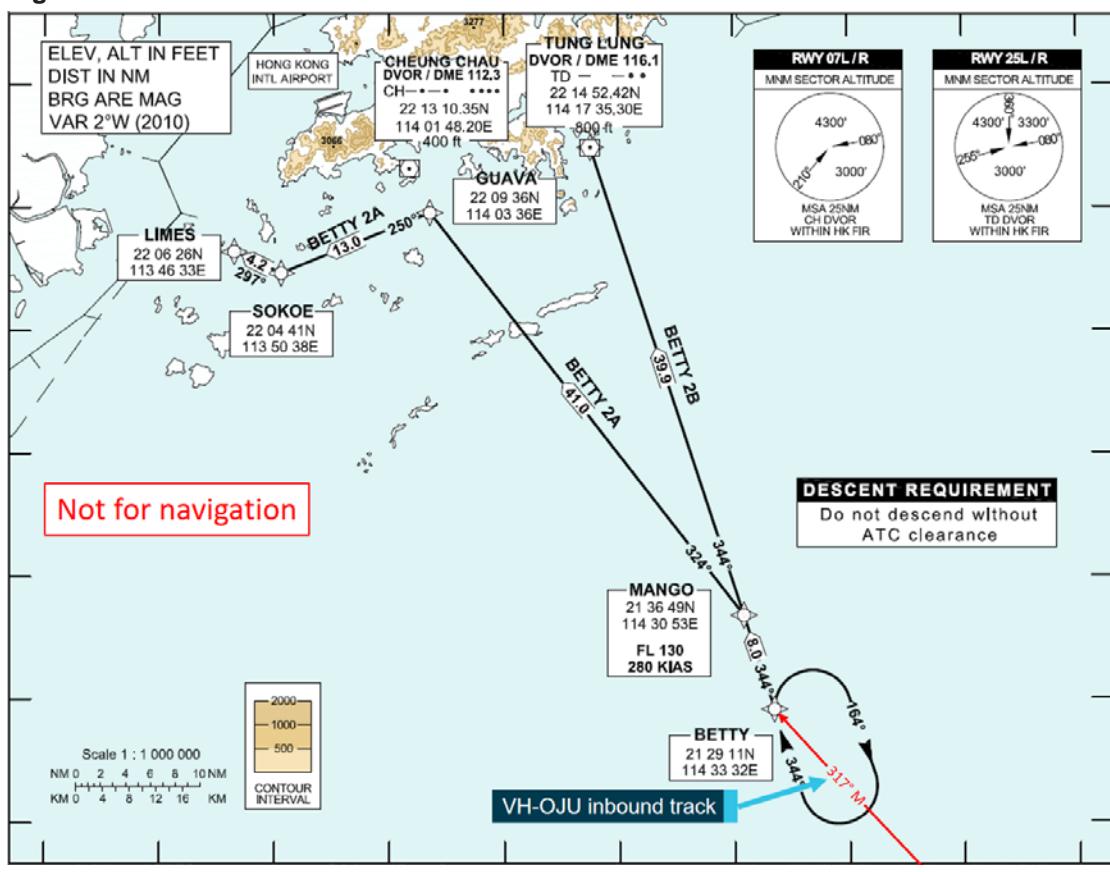
Comprehensive theory and practical training can ensure that flight crews have a complete understanding of aircraft systems and maintain effective manual handling skills. This training should provide flight crew with the knowledge to correctly configure the aircraft's automatic flight systems and manual handling skills to respond adequately to in-flight upsets.

The occurrence

On 7 April 2017, a Qantas Airways Boeing 747-438, registered VH-OJU, operated as scheduled passenger flight QF29 from Melbourne, Victoria, to Hong Kong International Airport, in the Hong Kong Special Administrative Region of the People's Republic of China. On board were 17 crew and 347 passengers. The captain operated as pilot flying and the first officer as pilot monitoring.¹

At about 1745 Hong Kong Time (HKT),² in daylight, the aircraft descended toward waypoint³ BETTY (Figure 1) with the autopilot engaged in lateral navigation (LNAV) and vertical navigation (VNAV) modes,⁴ and the autothrottle engaged. As the aircraft descended from flight level (FL) 300,⁵ the customer service manager (CSM) (following direction from the flight crew) advised the passengers to prepare for landing and fasten seatbelts, however, at this time, the fasten seatbelt sign was not illuminated.

Figure 1: BETTY 2A standard arrival route chart extract



The figure shows the position of the BETTY hold along with the inbound track of VH-OJU. Source: Hong Kong CAD, annotated by ATSB

¹ Pilot Flying (PF) and Pilot Monitoring (PM): procedurally assigned roles with specifically assigned duties at specific stages of a flight. The PF does most of the flying, except in defined circumstances; such as planning for descent, approach and landing. The PM carries out support duties and monitors the PF's actions and the aircraft's flight path.

² Hong Kong Time was Co-ordinated universal time +8 hours.

³ Waypoint: A defined position of latitude and longitude coordinates, primarily used for navigation.

⁴ Lateral navigation and vertical navigation modes: In the lateral navigation mode, the roll command is calculated by the flight management computer based on the active flight plan. The vertical navigation mode supplies pitch control in response to vertical navigation data from the active flight plan.

⁵ Flight level: at altitudes above 10,000 ft, an aircraft's height above mean sea level is often referred to as a flight level (FL). FL 300 equates to 30,000 ft.

The flight crew anticipated that air traffic control (ATC) would direct them to hold at waypoint BETTY, at about FL 150 to FL 160, and they used the aircraft flight management computer (FMC) to plan for the hold. The FMC provided a calculated target hold speed (Figure 2) of 223 kt at FL156, which was the FMC-calculated crossing level at waypoint BETTY. The crew verified this calculated speed by comparing it to the flaps-up manoeuvring speed (see *Hold speed* below) using a heuristic of adding 80 kt to the flaps-30 landing reference speed of 143 kt, resulting in 223 kt.⁶ The captain asked the first officer to input 225 kt above FL 150 as the target hold speed.

Figure 2: Example of the FMC route hold page with the target speed and the best speed highlighted



The FMC route hold page, showing the best speed indication (representative and not indicating incident data).

Source: Operator, annotated by ATSB

Prior to crossing BETTY, ATC descended the aircraft from FL 300 in steps. This positioned the aircraft above the planned descent profile. As the aircraft approached BETTY at FL 230, ATC instructed the flight crew to descend to FL 220 and hold at BETTY. The flight crew then entered 22,000 ft in the autopilot altitude selection window, which directed the FMC VNAV function to level at FL 220. However, the flight crew did not adjust the target hold speed in alignment with the higher-than-expected hold level. The flight crew later reported that they were not aware of a higher speed requirement for holding above FL 200.

At this time, service in the aircraft's forward cabin had been completed. The CSM, along with other cabin crewmembers from the forward sections, moved towards the rear of the aircraft to assist with preparing the rear cabin for landing. This led to more cabin crewmembers than normal being in the rear cabin.

While descending towards BETTY, the aircraft's speed reduced below both the target speed of 225 kt and the minimum manoeuvring speed, which was indicated on the pilot's flight display (PFD) as the top of an amber band (see Figure 5 in *Operational information* below).

At this time, the captain was reviewing the Hong Kong approach documentation and the first officer was looking out to the right of the aircraft in an attempt to identify aircraft traffic in the vicinity of the holding pattern. As a result, the captain and first officer did not identify the reducing

⁶ The flaps-up manoeuvre speed could be calculated using the addition of a speed increment of 80 kt to the flaps-30 landing reference speed.

speed. The second officer later reported observing the speed reducing close to, but not below, the selected speed of 225 kt.

At 1747:42, the flight data showed that the aircraft crossed BETTY at a speed of 222 kt, while descending through FL 227, with engine power at idle. The aircraft then began a right turn to enter the holding pattern. While still turning, the aircraft descended through FL 222 and the pitch angle⁷ began to increase as the autopilot prepared to level the aircraft at FL 220. Three seconds later, at 1747:59, the aircraft's bank angle increased to a maximum of 32 degrees, its speed reduced to 220 kt and the aircraft began experiencing pre-aerodynamic stall buffeting.⁸ The flight crew reported the stick shaker also activated, although the recorded flight data does not show a stick shaker activation at this time. The captain also later commented that he did not recall seeing the stall warning indication approaching the indicated speed on the PFD (see *Stall warning activation speed* below).

After the onset of the buffeting, flight data shows the autopilot was disconnected, most likely by the captain. The captain then pushed forward on the control column to reduce the aircraft's pitch angle and reduced the aircraft's bank angle. Due to a desire to remain within the protected airspace of the holding pattern, the captain did not roll to wings level as recommended by the operator's approach to stall recovery procedure (see Figure 7 in *Stall warning recovery procedure* below). The captain also did not disconnect the autothrottle as required by the procedure, however, he manually advanced the thrust levers. Due to concerns regarding an excessive increase in pitch resulting from a large power increase,⁹ he increased the engine power from about 37 per cent to about 73 per cent N1.¹⁰

The first officer observed the captain's actions and was satisfied that the appropriate actions had been undertaken. He did not identify, and therefore did not call out, that the stall recovery procedure had not been completed. As a result of the captain's actions, the aircraft accelerated slightly, the buffeting stopped and the aircraft continued descending.

Six seconds later, at 1748:05, the aircraft descended through FL 220, the speed increased to the selected 223 kt and the thrust reduced. At the same time, the captain pulled back on the control column to increase the pitch angle to prevent further descent. Four seconds later, the stick shaker activated. In response, the captain again pushed forward on the control column to reduce the aircraft's pitch angle and increased thrust slightly. The stick shaker deactivated and the aircraft continued descending. As the aircraft descended through FL 218, the captain pulled back on the control column to increase the pitch angle and the stick shaker again activated. In response, the captain again pushed forward on the control column to reduce pitch angle and the stick shaker deactivated. At about this time, the seatbelt sign was selected on.

Over the next nine seconds, the captain disengaged the autothrottle, increased power to greater than 90 per cent N1 and increased the selected speed to 252 kt. The oscillations reduced and the aircraft continued accelerating.

At 1748:31, the aircraft levelled off at FL 214 and the speed was increasing through 238 kt toward the selected speed. At about this time, the first officer alerted the captain that the aircraft had descended below the cleared level. In response, the captain asked the first officer to request a lower level from ATC, who immediately cleared the flight crew to descend to FL 210. The autopilot was then re-engaged in VNAV and LNAV modes with 21,000 ft in the altitude window of the mode

⁷ Pitch angle: the angle of the aircraft body as it moves about its lateral (wingtip-to-wingtip) axis in relation to the horizon.

⁸ Pre-aerodynamic stall buffeting occurs when the wing approaches the stall angle of attack. Airflow from the wing's upper surface begins to separate and become turbulent. The turbulent flow passes across the horizontal stabiliser and is felt through the aircraft as buffeting.

⁹ The underwing location of the engines, low on the airframe, imparted a large pitch up moment upon a large increase in engine power.

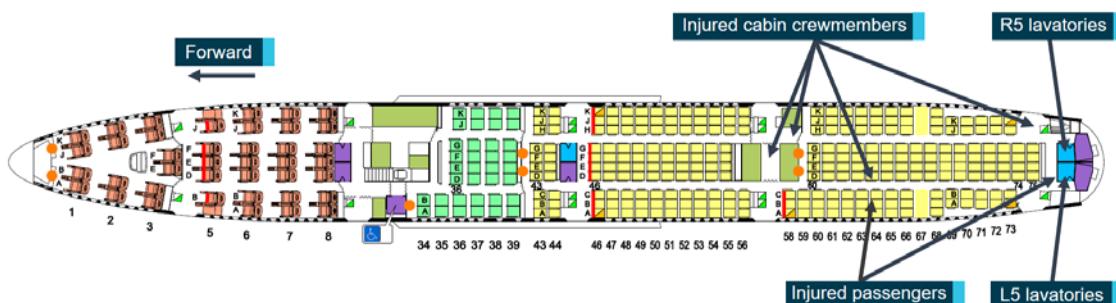
¹⁰ N1: the rotational speed of the low pressure compressor in a turbine engine.

control panel. However, as the altitude selector was not activated, 22,000 ft remained as the commanded altitude and the aircraft commenced climbing to FL 220.

As the aircraft climbed, ATC contacted the flight crew to confirm that they were descending to FL 210. The flight crew confirmed that they were descending and activated the 21,000 ft altitude selection. The aircraft then descended to FL 210 and re-joined the BETTY holding pattern. During the event, there was no loss of separation with any aircraft.

During the pilot-induced oscillations, the CSM, who was standing in the left aisle in the vicinity of rows 63 and 64 (Figure 3), struck the cabin ceiling before falling on a seat armrest, sustaining injuries. Five other cabin crewmembers also struck the ceiling, with three sustaining injuries. A passenger located in an L5 lavatory struck the cabin ceiling landing on the lavatory seat, resulting in minor injuries and damage to the lavatory fittings. A passenger in seat 63C who did not have her seatbelt fastened, was also injured.

Figure 3: VH-OJU main deck layout



The figure shows the aircraft main deck layout. The locations of the injured cabin crewmembers, injured passengers and L5 and R5 lavatories are identified. Source: Operator

After the aircraft stabilised, the CSM was alerted to the injured passenger in the L5 lavatory. The CSM provided assistance to this passenger and then conducted the call back procedure.¹¹ During the call back procedure, cabin crew advised the CSM of further injured passengers and cabin crewmembers.

As the aircraft tracked on the outbound leg of the holding pattern, the lavatory smoke alarm activated and the flight crew received a lavatory smoke alarm warning. The captain asked the first officer to request a priority landing from ATC. ATC immediately cleared the flight directly to Hong Kong International Airport.

The cabin crewmembers established that the smoke alarm originated at the R5 lavatories and that there was no evidence of smoke, fire or fumes. The CSM reported to the flight deck that they believed the smoke alarm to be a false alarm caused by the lavatory damage.

While approaching Hong Kong International Airport, the smoke alarm activated a further six times. The cabin crewmembers determined that these alarms were also false. The aircraft landed without further incident.

Four cabin crewmembers and two passengers received minor injuries during the incident and the aircraft cabin sustained minor damage.

¹¹ Call back: A procedure conducted after an incident, where each cabin crewmember contacts the CSM using the cabin interphone to advise of their welfare.

Context

Flight crew

Captain

The captain held an Air Transport Pilot Licence (Aeroplane), a multi-engine command instrument rating and a Class 1 Aviation Medical Certificate. The captain had over 24,000 hours of flying experience, of which over 10,000 hours were on the Boeing 747.

First officer

The first officer held an Air Transport Pilot Licence (Aeroplane), a multi-engine command instrument rating and a Class 1 Aviation Medical Certificate. The first officer had over 16,000 hours of flying experience, of which over 5,000 hours were on the Boeing 747.

The investigation assessed whether the captain or first officer were experiencing a level of fatigue known to have an effect on performance. The ATSB found no indicators that increased the risk of either crew experiencing this level of fatigue.

Second officer

The second officer held an Air Transport Pilot Licence (Aeroplane), a multi-engine command instrument rating and a Class 1 Aviation Medical Certificate. The second officer had over 8,000 hours of flying experience, of which over 5,000 hours were on the Boeing 747.

Meteorological information

As the aircraft entered the holding pattern, the aircraft recorded wind direction was 268°M and speed was 41 kt. The flight crew reported visual meteorological conditions with slight haze prevailed at the time of the occurrence.

The flight crew also reported experiencing smooth conditions prior to, and throughout, the event. There was little to no recorded turbulence. The ATSB therefore concluded that turbulence did not contribute to the pre-aerodynamic stall buffeting or stick shaker activations.

Aircraft information

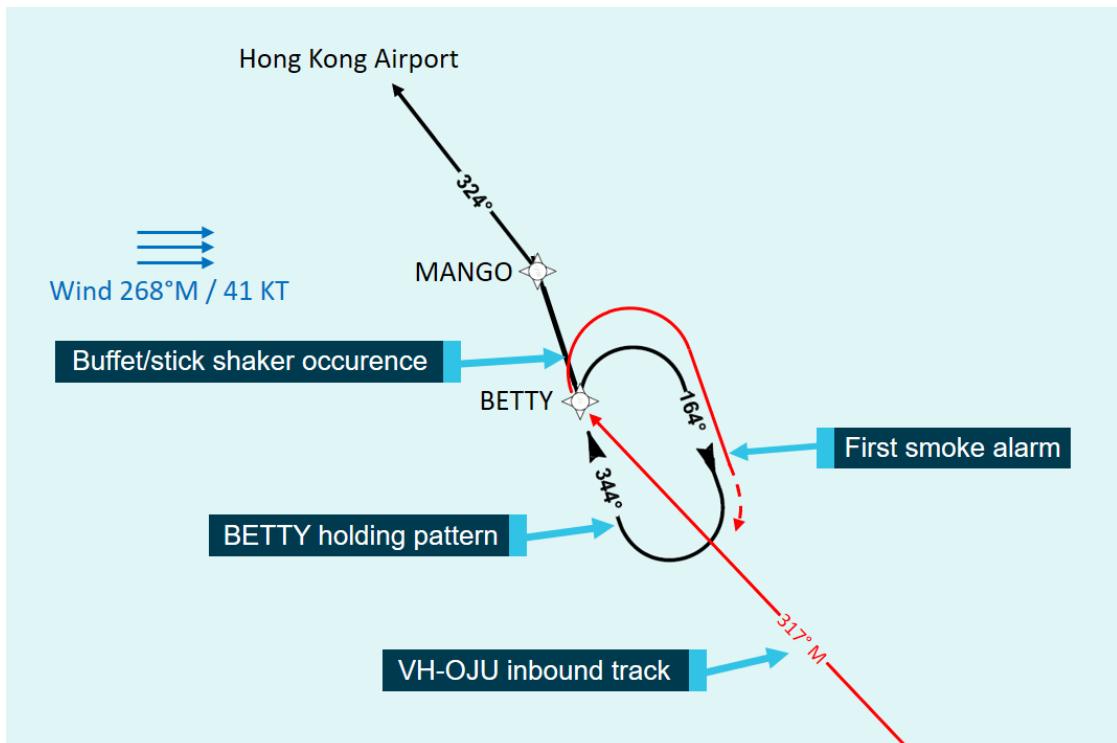
Autopilot holding with LNAV/VNAV active

When holding with LNAV active, the FMC tracks the holding pattern targeting a 25 degree bank angle up to a limit of 30 degrees of bank angle. The FMC computes holding patterns with constant radius turns based on the current wind and commanded speed.

The aircraft tracked 317°M as it crossed BETTY (Figure 4) and began a right turn, through a total of 207°, to track 164°M for the outbound leg of the pattern.

As the aircraft turned, the wind direction moved to a relative position behind the aircraft, increasing the aircraft's ground speed. The increased ground speed required a greater bank angle to achieve the targeted turn radius and outbound track spacing. The first officer also later commented that when the holding entry required a turn in excess of 180°, the autopilot would initially command a bank greater than 30 degrees.

The aircraft manufacturer commented that the autopilot has the capability to increase bank angle beyond the FMC commanded angle. The manufacturer further commented that it was not unusual that the increasing ground speed led the autopilot to increase bank angle with an overshoot up to 32 degrees to achieve the FMC target turn radius and outbound track spacing.

Figure 4: BETTY holding pattern

The figure shows the BETTY holding pattern along with the recorded wind conditions, the approximate track of VH-OJU as it entered the holding pattern and the locations of the buffet/stick shaker occurrence and first smoke alarm. Source: Hong Kong Civil Aviation Department, annotated by ATSB

Operational information

Hold speed

The FMC calculated target hold speed and target level are based on the aircraft's gross weight and programmed VNAV descent profile (see Figure 2). Below FL 150, this speed is based upon the flaps 30 landing reference speed with the addition of a speed increment. The speed increment varies with aircraft weight and is designed to provide a manoeuvre margin¹² equivalent to a level turn at 40 degrees angle of bank or 1.3 G of vertical acceleration.

Above FL 200, the FMC calculated hold speed corresponds to the minimum drag speed.¹³

Between FL 150 and FL 200 the FMC target hold speed is calculated using a linear interpolation between the speeds calculated for FL 150 and FL 200.

The FMC also calculates best speed, which is displayed on the hold page (see Figure 2). The operator's flight crew operations manual (FCOM) contained the following guidance on the best speed function on the hold page of the FMC:

Displays best holding speed for airplane gross weight, altitude, and flap setting.

The displayed best speed may be different to the target hold speed in the hold planning stage as the hold may be planned using an altitude different to the current altitude. If no target speed is selected, the FMC will select the best speed.

The aircraft manufacturer provided the following advice regarding the hold speed for this event:

At 22,000 feet, the optimum holding pattern airspeed would have been approximately 240 knots based upon the event gross weight.

¹² Manoeuvre margin is the available manoeuvre capability of the aircraft prior to activation of the stall warning system.

¹³ Minimum drag speed is the speed at which total aircraft drag, and therefore fuel consumption, is lowest.

For holding when hold speeds are not available from the FMC, the operator's flight crew training manual (FCTM) provided the following guidance:

Recommended holding speeds can be approximated by using the following guidance until more accurate speeds are obtained from the quick reference handbook:

- Flaps up manoeuvre speed approximates the minimum fuel burn speed and may be used at low altitudes¹⁴ (approximated by adding 80 kt to the calculated flaps 30 landing reference speed)
- If the FMC calculated hold speed is not available, when holding above FL 200 recommended holding speeds can be approximated by adding 100 kt to the calculated flaps 30 landing reference speed.

Following the above guidance would have provided an approximate hold speed of 243 kt.

The programmed VNAV descent profile crossed BETTY at FL 156. The FMC calculated a target hold speed of 223 kt at FL 156 for holding at BETTY. When ATC instructed the flight crew to hold at FL 220, the captain instructed the first officer to input a target speed of 225 kt at or above FL 150 into the FMC.

While hold speed data was available from the FMC, the flight crew were not aware that a different speed was required above FL 200 and used speed data for FL 156 for holding at FL 220.

Flight crew high altitude hold speed knowledge and training

The flight crew reported that in practice they used the flaps up manoeuvring speed and then added an arbitrary buffer when selecting a hold speed. This is contrary to the FCTM guidance, and there was no other operator or manufacturer guidance recommending this procedure or the size of the buffer to be used. The investigation found that the flight crew were not aware of the function, or use of, the best speed in the hold page of the FMC.

The operator provided training for flight crew on holding patterns and speeds during ground school training prior to the commencement of operations on the aircraft type and during recurrent operational training.

The operator reported that there were no documented training exercises where a holding pattern was conducted at high altitude (above FL 200). Holding patterns were generally conducted at lower levels prior to commencing a landing approach.

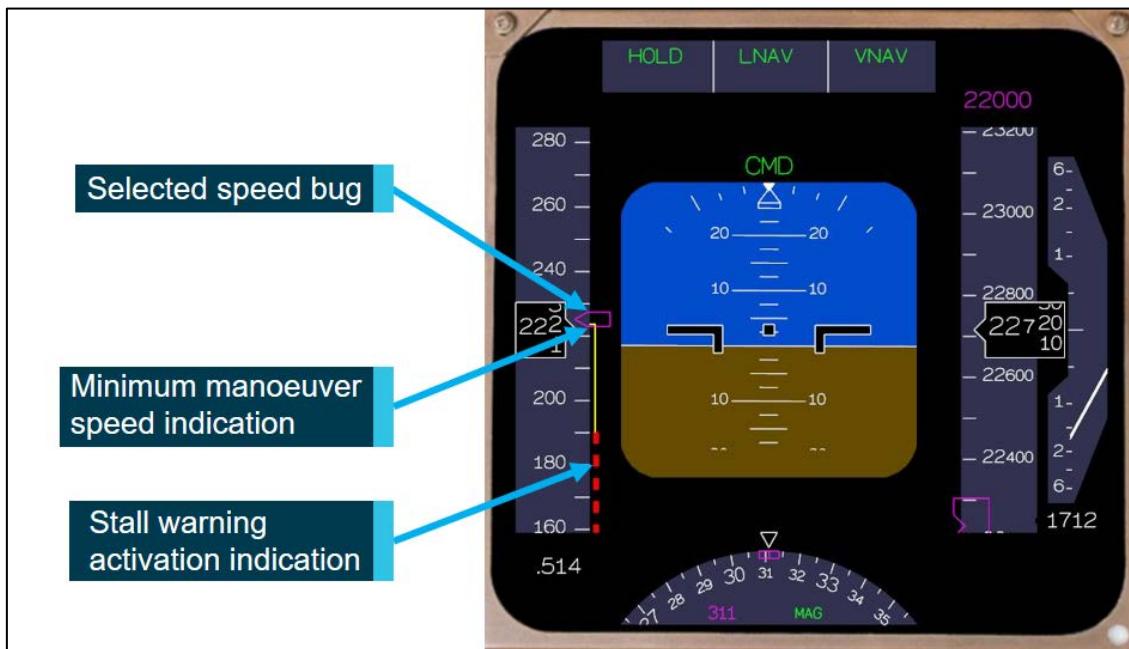
Minimum manoeuvre speed

The aircraft's FMC calculated minimum manoeuvre speed provides 0.3 G of margin above the onset of pre-aerodynamic stall buffet. This is equivalent to a level turn at 40 degrees angle of bank or 1.3 G of vertical acceleration.

The minimum manoeuvre speed is indicated by the top of an amber band on the speed tape of the PFD (Figure 6: Figure 5). When operating at a speed within the amber band, reduced manoeuvre capability exists.

¹⁴ The FCTM guidance advised that the flaps up manoeuvring speed guaranteed at least full manoeuvre capability, or at least 40° of bank to stall warning activation 'within few thousand feet of the airport altitude' and noted that 'less manoeuvre margin to stick shaker exists for a fixed speed as altitude increases'.

Figure 5: Representation of the primary flight display as the aircraft crossed BETTY



This figure shows a representative presentation of the primary flight display as the aircraft crossed BETTY, derived from recorded flight data. The minimum manoeuvre speed amber band and selected speed bug are annotated. Source: ATSB

Stall warning activation speed

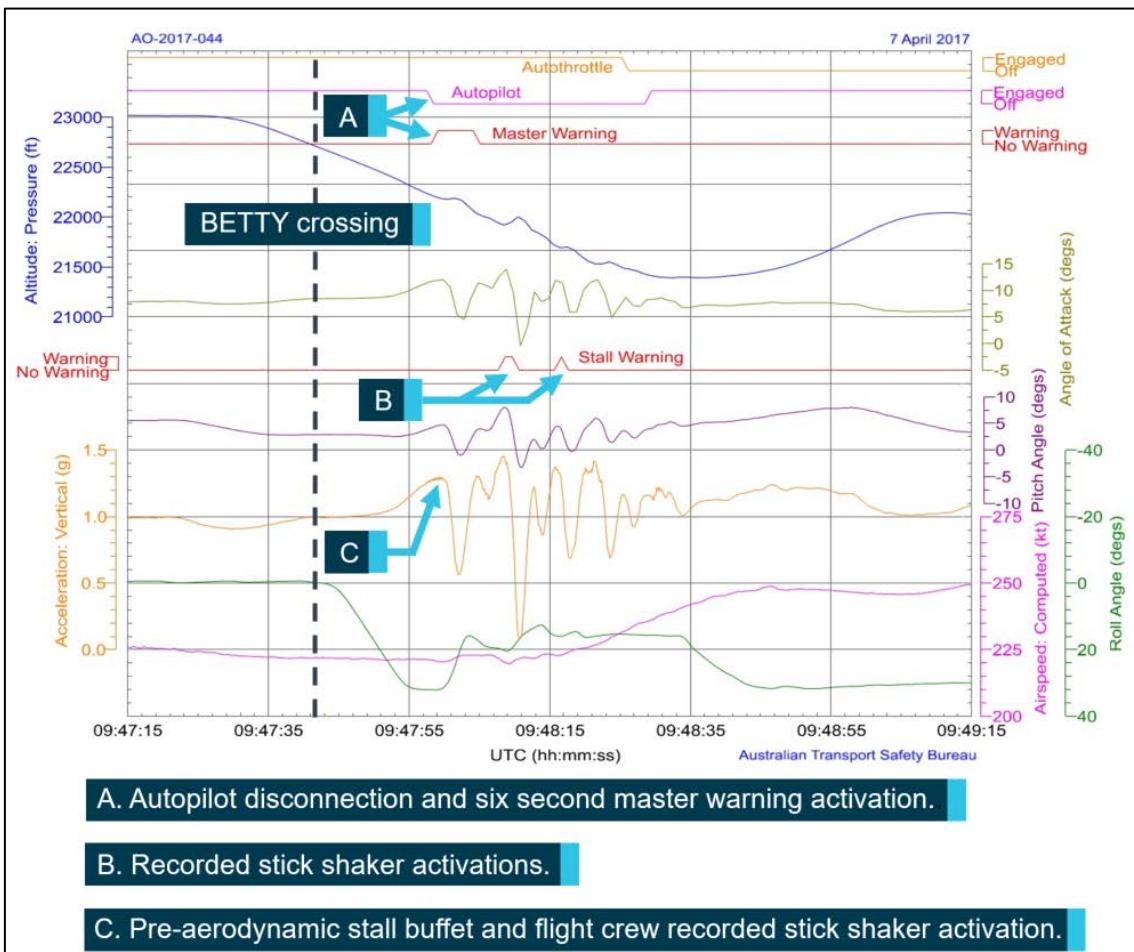
The speed at which the aircraft's stall warning system would activate was indicated on the PFD as a red dashed line (see Figure 5 above).

This indication was dynamic and moved in accordance with various factors such as aircraft configuration, gross weight and aircraft manoeuvring. This provided the flight crew with a real-time indication of the stall warning activation speed.

Recorded flight data

Flight data was available from the flight data recorder and the quick access recorder.

Figure 6: Graphical representation of quick access recorder data



The figure shows a graphical representation of recorded flight data from stick shaker incident significant points of the occurrence are annotated. Source: ATSB

The aircraft manufacturer reviewed the flight data and determined that during the stick shaker occurrence, the aircraft did not enter a stall. The manufacturer provided the following analysis:

For the 747-400, at the event flight condition, the estimated maximum vane angle of attack before stall is achieved would be approximately five degrees.¹⁵ During this occurrence, the highest recorded vane angle of attack was approximately -0.5 degrees, resulting in significant margin to the estimated maximum vane angle of attack when stick shaker activated.

The recorded data did not show a stick shaker activation at the time the autopilot disconnected,¹⁶ as described by the flight crew. At this time, the recorded vane angle of attack reached a value about 0.3 degrees below the estimated angle for stick shaker activation. However, as the stick shaker activation parameters are recorded at a rate of one sample per second, it is possible that the stick shaker activated momentarily and was not captured by the flight recorders.

The recorded vertical acceleration at the time of the initial buffet and possible stick shaker activation was 1.29 G. The maximum vertical acceleration value recorded during the occurrence was 1.45 G, the minimum recorded value was 0.09 G.

¹⁵ Five degrees vane angle corresponds to 13 degrees body angle of attack.

¹⁶ The cockpit voice recorder was not available for analysis. Therefore, the investigation could not determine if the stick shaker activated during the initial buffet onset.

Stall recovery procedures and training

Stall warning recovery procedure

The aircraft was fitted with a stick shaker device to provide warning to the flight crew that the aircraft was approaching an aerodynamic stall. When activated, the stick shaker vibrated both control columns, providing an aural and tactile warning indication.

The operator procedures included the 'approach to stall or stall warning' procedure. In case of a stall warning, the procedural steps to be followed are shown in Figure 7:

Figure 7: Approach to stall or stall recovery procedure

Approach to Stall or Stall Recovery	
Pilot Flying	Pilot Monitoring
<p>Initiate the recovery</p> <ul style="list-style-type: none"> Hold the control column firmly. Disengage autopilot and disconnect autothrottle. Smoothly apply nose down elevator to reduce the angle of attack until buffet or stick shaker stops. Nose down stabilizer trim may be needed. 	<p>Monitor altitude and airspeed.</p> <ul style="list-style-type: none"> Verify all required actions have been done and call out any omissions. Call out any trend toward terrain contact.
<p>• Continue the recovery:</p> <ul style="list-style-type: none"> Roll in the shortest direction to wings level if needed. Advance thrust levers as needed. Retract the speedbrakes. Do not change gear or flap configuration, except During liftoff, if flaps are up, call for flaps 1. 	<p>• Monitor altitude and airspeed.</p> <ul style="list-style-type: none"> Verify all required actions have been done and call out any omissions. Call out any trend toward terrain contact. Set the FLAP lever as directed.
<p>• Complete the recovery:</p> <ul style="list-style-type: none"> Check airspeed and adjust thrust as needed. Establish pitch attitude. Return to the desired flight path. Re-engage the autopilot and autothrottle if desired. 	<p>• Monitor altitude and airspeed.</p> <ul style="list-style-type: none"> Verify all required actions have been done and call out any omissions. Call out any trend toward terrain contact.

Source: Operator

The recorded data showed that during the recovery after the initial buffet and possible stick shaker activation, the captain did not disconnect the autothrottle. While he reduced the bank angle, he did not level the wings or advance the thrust levers as needed to effect recovery. Nor were these actions completed during the second and third recovery attempts.

The autothrottle was not disconnected and the thrust levers were not advanced as needed to effect recovery until the fourth oscillation. After this increase in thrust, speed increased sufficiently for the captain to arrest the descent and stabilise the aircraft without further stick shaker activations.

During the oscillations, the first officer did not identify or call out the incomplete actions, as required by the procedure.

Approach to stall and stall recovery training

The operator provided approach to stall and stall recovery training to flight crew during type conversion training and their recurrent operational training in accordance with manufacturer recommendations and as approved by the Civil Aviation Safety Authority. Each flight crew

member had undergone this training on multiple occasions, exposing them to various stall recovery scenarios.

The stall recovery scenario conducted in the most recent exercise was simulated with the aircraft:

- configured with landing gear down and flaps 20
- positioned on the downwind leg of a circuit (about 1,500 ft above ground level)
- weight of 266,000 kg.

During the exercise, a first officer, as pilot flying, closes the thrust levers while in level flight just before turning onto the base leg of the circuit. The crew should recover at first stall indication, using the correct recovery procedure. The exercise was then repeated with the captain as pilot flying.

The captain last underwent this training on 4 April 2017, three days prior to the incident flight. The first officer had last undergone stall recovery training in October 2014 and the second officer in February 2017.

The scenarios all commenced with the crew reducing the engine power to idle prior to the stick shaker activating, and all recoveries were initiated with engine power at idle.

In their internal investigation report, the operator provided the following analysis of the stall recovery training:

The investigation could not find any trained scenarios that approximated the conditions experienced by QF29; that is; stick shaker activation while manoeuvring at altitude. By limiting stick shaker recovery to non-realistic scenarios, with considerable lead in time giving Flight Crew ample opportunity to prepare for the forthcoming manoeuvring, there is limited exposure to the complexity of the required recovery actions at altitude in real life scenarios...

...Further enhancing stick shaker recovery by including realistic scenarios, during training may provide increased exposure for Flight Crew of the relationship between control column movement and true airspeed, preventing further Flight Crew over-controlling events brought about by startle effect.

Smoke alarm activations

The ATSB could not determine the reason why the smoke alarms in the R5 lavatory activated after the upset. However, the lavatories at R5 and L5 shared a ventilation system and it may have been that dust, from the lavatory fittings detaching in the L5 lavatory, activated the R5 smoke alarm.

During the smoke alarm activations, cabin crewmembers responded appropriately and acted in accordance with procedures. Additional crewmembers in the rear aircraft cabin also supported the response to the smoke alarm.

ATSB research report

In 2013, the ATSB released the research report [AR-2012-172 Stall warnings in high capacity aircraft: The Australian context](#).

This research report reviewed 245 stall warnings and stall warning system events reported to the ATSB over a 5-year period (2008–2012). The ATSB identified 33 serious and higher risk incidents in which a stall warning occurred, and in several cases the stall warning speed was higher than normal (due to a higher vertical acceleration (G) factor in a turn, or an incorrect reference speed switch setting). The report contained the following safety message:

Stall warnings occur in normal operations, and are normally low risk events. In Australia, even the most serious events have not resulted in a loss of control, and have been effectively managed by flight crew to prevent a stall from occurring. To avoid higher risk stall warning events, pilots are reminded that they need to be vigilant with their awareness of angle of attack and airspeed.

Safety analysis

Identification of necessity to recalculate hold speed

Prior to arriving at BETTY, the VNAV profile in the flight management computer (FMC) calculated holding at between FL 150 and FL 160. When selecting a target speed, the flight crew verified the FMC provided speed by comparing the speed to the flaps up manoeuvre speed calculation.

However, the flight crew training manual advised that the flaps up manoeuvring speed guaranteed at least full manoeuvre capability, to stall warning activation at low altitudes. The flight crew were not aware of the requirement to use a different speed calculation verification for altitudes above FL 200.

Had the crew recalculated the hold speed for FL 220 using the flight management computer, it would have provided a target hold speed of 240 kt. In this case, the flight crew likely did not have an adequate understanding of how the FMC calculated the target hold speed. They also did not understand the use of the best speed provided on the hold page in the FMC. Using best speed would have provided the crew with a hold speed for the actual aircraft weight, altitude and configuration at that time. Orasanu (2010) outlines that decision errors in aviation are often a result of a lack of knowledge:

[They] typically are not slips or lapses in carrying out an intention, but errors of intention itself (Norman, 1981). The decision maker acts according to his/her understanding of the situation, and the source of error is in the decision maker's knowledge base or in the process of reaching a decision.

The selection of an incorrect hold speed resulted in the aircraft entering the hold with a selected speed 15 kt below the required speed. Using the best speed in the FMC hold page or recalculating the hold speed using the FMC for the higher level would have resulted in the use of a speed which provided sufficient margin to prevent a stick shaker activation.

Absence of hold speed re-evaluation procedure

Neither the operator or aircraft manufacturer provided procedures or guidance which stated that a hold speed was required to be re-evaluated for a change in hold level when a speed was selected in the FMC during the planning stage of a descent. Therefore, the flight crew did not have the requisite knowledge to identify the need to re-evaluate the selected speed.

Reason (2008) explains that decision errors, such as not re-evaluating the hold speed, can be as a result of a 'failure to detect a signal or problem', and are more likely under conditions including 'when the person did not expect to find a problem in that location...'. Detecting a problem, or an absence of an action can be particularly difficult when there are no cues to identify an issue. In this case, there was no procedural prompt for the flight crew to re-evaluate the speed for the higher level and select the correct speed. Therefore, the need to re-evaluate the hold speed relied on the crew's knowledge of the higher speed requirement above FL 200.

This resulted in the remaining protections against a low speed condition being the minimum manoeuvring and stall warning activation speed indications on the pilot's flight display.. At the time the speed reduced below both the selected speed and the minimum manoeuvring speed, the flight crew's attention was focussed on other operational matters resulting in the crew not identifying the reduced speed.

In summary, a requirement to re-evaluate the speed for the higher than planned hold level would likely have provided the crew with a prompt to reselect the speed, which in turn would provide an adequate margin above the minimum manoeuvring speed.

Crew recognition of low speed prior to entering the hold

As the aircraft entered the holding pattern, the delay in the autothrottle system detecting and effecting changes in aircraft speed allowed the speed to reduce to 220 kt—below both the selected speed of 225 kt and the minimum manoeuvring speed of 223 kt.

These speeds, along with the stall warning activation speed were displayed on the PFD, but the flight crew did not detect that the speed had reduced as their attention was on other operational tasks. Reason (2008) outlines why focusing one's attention on one task can be to the detriment of noticing other important tasks:

...attention is a limited resource. Direct it at one thing and it is withdrawn from another. When attention is 'captured' by something unrelated to the task at hand, actions often proceed unintentionally along some well-trodden pathway: strong habit intrusions

Not noticing a visual indication well within one's visual scan can be a common outcome to a crew's attention being focused elsewhere, as explained by Wickens and McCarley (2008):

Change blindness...occurs when an observer fails to detect an event (e.g. discreet change) in the environment around him...[and is a] failure to notice that something is different from what it was...How do lapses occur? Very often, [change blindness] is a failure of attention. Data indicate that changes are likely to go unnoticed if they are not attended when they occur...[i.e.] if the observer is looking away...

It can be difficult to detect discreet changes, even with visual indicators of limits (i.e. speed bug on the PFD) in view of the crew, when attention is on other operational matters. In turn, this reduced the likelihood that they could detect an undesirable aircraft condition.

Pre-aerodynamic stall buffet and probable stick shaker activation

As the aircraft turned to enter the holding pattern, the bank angle increased and the aircraft began to transition from descent to level flight. The effects of these manoeuvres combined to increase the vertical acceleration and wing angle of attack. The increasing angle of attack initiated pre-aerodynamic stall buffeting.

At this time, although it was not recorded on the flight data, all flight crewmembers reported a stick shaker activation. The recorded angle of attack also indicated that a stick shaker likely occurred. The manufacturer advised that an activation of less than one second in duration may occur without being captured in the flight recorder data.

Pilot induced oscillations and cabin injuries

At the time of the initial buffeting and probable stick shaker activation, the captain commenced the approach to stall and stall recovery actions required within the operating procedures. However, after this, a number of the other actions required by procedures were not completed, including the following:

- due to a desire to remain within the protected airspace of the holding pattern, the wings were not levelled
- the autothrottle was not disconnected
- due to the captain's concern regarding the pitch up moment resulting from a large engine power increase, engine power was not manually increased sufficiently to effect recovery
- the first officer assessed that the actions had been completed correctly and did not identify or therefore call out the missed actions.

After the captain did not complete the approach to stall recovery procedure, the aircraft entered a series of pilot induced oscillations during which the crew's premature attempts to arrest the rate of descent without increasing power as needed and before the speed had increased sufficiently, resulted in a further two stick shaker activations. After a fourth oscillation (during which the flight

crew did not recall a stick shaker activation and an activation was not recorded), the engine power was increased sufficiently to accelerate the aircraft to enable the flight crew to complete the recovery.

The ATSB considered whether the captain's performance was affected by a startle response, which is defined by Landman and others (2017) as a 'physiological reaction to a highly salient stimulus' (e.g., sudden, intense, or threatening; Rivera, Talone, Boesser, Jentsch, & Yeh, 2014). Rivera and others (2014) add that it disrupts 'cognitive processing and can negatively influence an individual's decision making and problem solving abilities'. They outline that the reaction can result in the following:

Studies have determined that motor response performance following a startling stimulus is disrupted for approximately 0.1 s to 3 s for simple tasks (May & Rice, 1971; Sternbach, 1960; Thackray, 1965)...In more complex motor tasks...startle may impact performance for up to 10 s following a loud intensity signal (Thackray & Touchstone, 1970).'

Rivera and others (2014) also stated that 'one must also consider the time to cognitively recover after a startling stimulus'. Within this same reference citing Bürki-Cohen (2010), they outline the difference between startle and surprise

...there are distinctive conceptual, behavioral, and physiological differences between the startle reflex and the surprise emotion.

In contrast to startle, which always occurs as a response to the presence of a sudden, high-intensity stimulus, surprise can be elicited by an unexpected stimulus or by the unexpected absence of a stimulus. Surprise can be described as a combination of physiological, cognitive, and behavioral responses, including increased heart rate, increased blood pressure, an inability to comprehend/analyze, not remembering appropriate operating standards, "freezing"...

In this case, it was not determined as to whether the tactile stimulus of the stick shaker and the aural alert was sufficient to elicit a startle response. However, the reaction of the captain in undertaking the *initial* approach to stall recovery did not largely appear to be adversely affected, as most actions were completed and the omitted or incomplete actions resulted from deliberate decisions. When then considering the *continuation* of the recovery steps, he was also able to outline the reasons for his actions, which do not necessarily demonstrate a negative influence on his decision making or problem solving abilities.

With respect to the first officer, he perceived that the absence of his call-outs required of the pilot monitoring position (including not calling out any omissions during the recovery continuation and completion) were a result of experiencing the startle effect. Given that the approach-to-stall recovery actions overall were completed in about 10 seconds, this is possible. However, there was insufficient evidence to determine whether his was a response to a sudden, high-intensity stimulus. His reaction may appear more consistent with surprise, whereby there was a cognitive mismatch between new information and expectations, especially as he had no expectation of stick shaker activation.

The recorded flight data shows that during the oscillations, the aircraft underwent significant variations in vertical acceleration. The pilot-induced oscillation occurred at a time when the fasten seat belt sign was not illuminated and cabin crewmembers were standing in the rear cabin, completing the cabin preparation for landing. The variations in vertical acceleration resulted in several cabin crewmembers and passengers impacting the cabin ceiling and furnishings, sustaining minor injuries. The impact of occupants to the cabin ceiling and furnishings resulted in damage to these furnishings, in particular an L5 lavatory. This damage resulted in the L5 and R5 lavatory smoke alarm activations.

Limited guidance in high altitude manual handling and stall recovery training

All flight crew undertook simulator training exercises as part of a cyclic training schedule. The most recent exercise undertaken by the crew included an approach to stall recovery scenario exercise, which was simulated at low altitude and with the aircraft configured with flaps and landing gear extended. In this instance, the simulated aircraft response would be markedly different to that of an aircraft operating at higher altitudes (such as FL 200 and above) and with the landing gear and flaps retracted.

In this case, the flight crew had undergone this cyclic training exercise, including the captain who completed the training three days prior to the occurrence. In addition, after the event, they could recall the correct recovery actions indicating that the training was effective in providing the crew with the required knowledge to effect the recovery.

However, this training exercise did not familiarise the crew with the manual handling of the aircraft at higher altitudes. Hasleback (2014) states:

From [a pilot's initial training onwards], pilots are faced with automation induced skill degradation (Balfe, Wilson, Sharples, & Clarke, 2012), caused by the automation taking over the responsibility for tasks previously performed by the human operators (Parasuraman & Riley, 1997).

There are ways to overcome this. In a study examining the relationship between pilot manual handling performance and recency, Ebbatson (2009) outlined that 'significant relationships are identified between pilots' recent flying experience and their manual control strategy'. Hasleback and others (2014) summarised this study to show that 'recent flight practice including manual flying occurring a few weeks prior to the experiment had more influence on the measured performance than flight hours accumulated over a pilot's entire career'.

Orlady and Orlady (1999) explain the importance of including manual handling exercises in training:

Using today's automation more efficiently does not mean that today's pilots do not need all of the old skills and knowledge... They need all of the old skills plus the new skills required by the automation...Manual skills must be a part of any recurrent or transition training and checking program in addition to the emphasis given to the proper use of the automatics.

In this case, the opportunity for flight crew to practice their high altitude manual handling skills was limited, which in turn limited the ability of flight crews to retain the necessary manual handling skills for stall recovery at higher altitudes. As a result, the flight crew did not adequately respond to the initial buffet and probable stick shaker activation, leading to the in-flight upset.

Use of seatbelts

Prior to the occurrence, the cabin crewmembers prepared the cabin for arrival at Hong Kong. This included an announcement to fasten seatbelts, however, at this time, the fasten seatbelt sign was not illuminated.

At the time of the in-flight upset, a passenger was located in the L5 lavatory and cabin crewmembers were in the rear cabin preparing for arrival. During the upset, the aircraft cabin was subject to large variations in vertical acceleration. Due to the unexpected nature of the event, neither the cabin crewmembers or the passenger in the L5 lavatory, who did not have a seatbelt available, were seated and secured at the time of the event. As a result, four cabin crewmembers and the passenger in the L5 lavatory sustained minor injuries.

A passenger seated in seat 63C did not have their seatbelt fastened. During the upset, this passenger impacted cabin furnishings and sustained minor injuries. Other seated passengers did have seatbelts fastened and as a result were not injured.

In-flight upsets, while rare, can have the potential to cause injuries. Evidence from this incident along with other incidents demonstrates that while seated, keeping a seatbelt fastened and secure significantly reduces the likelihood of being injured during an upset.

Findings

From the evidence available, the following findings are made with respect to the stick shaker activation event involving Boeing 747, VH-OJU, that occurred 110 km SE of Hong Kong International Airport (BETTY IFR), on 7 April 2017. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Safety issues, or system problems, are highlighted in bold to emphasise their importance.

A safety issue is an event or condition that increases safety risk and (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 operating environment at a specific point in time.

Contributing factors

- After overwriting the hold speed in the flight monitoring computer, the flight crew did not identify the need to re-evaluate the hold speed for the higher than expected hold level.
- Prior to entering the hold, the aircraft's speed reduced below both the selected and minimum manoeuvring speeds. The crew did not identify that the aircraft was operating below these speeds.
- The reduced speed coincided with the turn to enter the holding pattern and the level capture. These factors resulted in pre-aerodynamic stall buffeting and probable stick shaker activation.
- The pilot flying attempted to arrest the rate of descent prior to completing the approach to stall actions. The pilot monitoring did not identify and call out the incomplete approach to stall recovery actions. These combined actions led to pilot induced oscillations and further stick shaker activations.
- **The operator provided flight crew with limited training and guidance in stall prevention and recovery techniques at high altitudes or with engine power above idle.** (Safety issue)
- The passenger in seat 63C was not wearing a seatbelt at the time of the stick shaker activations.

Other safety factor

- **The operator provided flight crew with limited training and guidance relating to the need for crew to re-evaluate their holding speed for a change in altitude (specifically above flight level 200).** (Safety issue)

Safety issues and actions

The safety issue identified during this investigation is listed in the Findings and Safety issues and actions sections of this report. The 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 directly involved parties were provided with 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.

The initial public version of these safety issues and actions are repeated separately on the ATSB website to facilitate monitoring by interested parties. Where relevant, the safety issues and actions will be updated on the ATSB website as information comes to hand.

Stall prevention and recovery at high altitudes

Number:	AO-2017-044-SI-001
Issue owner:	Qantas Airways
Operation affected:	Aviation: Air transport
Who it affects:	Qantas Airways Boeing 747 flight crew

Safety issue description:

The operator provided flight crew with limited training and guidance in stall prevention and recovery techniques at high altitudes or with engine power above idle.

Proactive safety action taken by Qantas Airways

Action number: AO-2017-044-NSA-009

The operator commenced retraining of all pilots in stall warning recovery scenarios and amended recurrent lesson plans to incorporate more complex stall warning recovery events. The operator also updated lesson plans and distributed educational material to all flight crew.

Current status of the safety issue

Issue status: Adequately addressed

Justification: The retraining of flight crew and amended lesson plans incorporating more complex stall warning recovery training, along with the provision of further education material, enables flight crew to be adequately prepared to recover from stall warning activations at high altitudes or with engine power above idle.

Re-evaluating hold speeds for a change in altitude

Number:	AO-2017-044-SI-02
Issue owner:	Qantas Airways
Operation affected:	Aviation: Air transport
Who it affects:	Qantas Airways Boeing 747 flight crew

Safety issue description:

The operator provided flight crew with limited training and guidance relating to the need for crew to re-evaluate their holding speed for a change in altitude.

Proactive safety action taken by Qantas Airways

Action number: AO-2017-044-NSA-010

Qantas Airways amended the Boeing 747-400 flight crew training manuals relating to hold speed selection to provide enhanced holding pattern information to flight crew. They also updated ground school lesson plans and information to ensure standardised flight crew training and ensure holding pattern training was adequately addressed during flight crew training.

Current status of the safety issue

Issue status: Adequately addressed

Justification: Updated training manuals and lesson plans provided flight crew with the requisite knowledge and guidance to adequately prepare an aircraft for changes in holding level.

Proactive safety action

The operator reviewed the training and guidance provided to other Boeing aircraft types in its fleet, the 787 and 737, and made the following changes:

Training and guidance

The operator amended recurrent lesson plans for the 787 and 737 fleets to incorporate more complex stall warning recovery events. The operator also updated lesson plans and distributed educational material to all flight crews.

The operator amended the 787 and 737 flight crew training manuals relating to hold speed selection to provide enhanced holding pattern information to flight crew. They also updated ground school lesson plans and information to ensure standardised flight crew training and ensure holding pattern training was adequately addressed during flight crew training.

General details

Occurrence details

Date and time:	7 April 2017 – 0948 UTC	
Occurrence category:	Serious incident	
Primary occurrence type:	Stall warning	
Location:	110 km SE of Hong Kong Airport (BETTY IFR)	
	Latitude: 21° 29.23' N	Longitude: 114° 30.73' E

Pilot details – Captain

Licence details:	Air Transport Pilot (Aeroplane) Licence
Aeronautical experience:	Approximately 24,556 hours
Last flight review:	3 April 2017

Pilot details – First officer

Licence details:	Air Transport Pilot (Aeroplane) Licence
Aeronautical experience:	Approximately 16,400 hours
Last flight review:	12 November 2016

Pilot details – Second officer

Licence details:	Air Transport Pilot (Aeroplane) Licence
Aeronautical experience:	Approximately 8,555 hours
Last flight review:	6 February 2017

Aircraft details

Manufacturer and model:	The Boeing Company 747-438	
Year of manufacture:	1999	
Registration:	VH-OJU	
Operator:	Qantas Airways	
Serial number:	25566	
Type of operation:	Air transport high capacity - passenger	
Persons on board:	Crew – 17	Passengers – 347
Injuries:	Crew – 4 (Minor)	Passengers – 2 (Minor)
Damage:	Minor	

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- Operator
- Boeing (manufacturer)
- Aircraft crew
- Hong Kong Civil Aviation Department

References

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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, customer service manager, Qantas, the Civil Aviation Safety Authority, and Boeing.

Any submissions from those parties were reviewed and where considered appropriate, the text of the draft report was amended accordingly.

Australian Transport Safety Bureau

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; 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 operations involving the travelling public.

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 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.

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.

Investigation

ATSB Transport Safety Report

Aviation Occurrence Investigation

In-flight upset involving Boeing 747-438, VH-OJU
110 km SE of Hong Kong Airport, on 7 April 2017

AO-2017-044
Final – 27 March 2019

Australian Transport Safety Bureau

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