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Australian Transport Safety Bureau

Flight envelope protection event involving an Airbus A320, VH-VFJ

Near Auckland, New Zealand, 7 September 2013

ATSB Transport Safety Report

Aviation Occurrence Investigation

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Addendum

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Flight envelope protection event involving an Airbus A320, VH-VFJ

What happened

On the morning of 7 September 2013, an Airbus A320 aircraft, registered VH-VFJ, was being operated on a scheduled passenger service from Christchurch to Auckland, New Zealand. The first officer (FO) was designated as the pilot flying. The crew was cleared by air traffic control (ATC) via the DAVEE 3C arrival for the Required Navigation Performance (RNP) Y[1] approach to runway 23 Left (23L) at Auckland.

During descent, the crew complied with an ATC request to maintain 280 kt until 5,000 ft above mean sea level (AMSL). Passing about 6,800 ft, and after having been cleared for the approach by ATC, the crew armed the auto-flight system final approach mode by pressing the approach (APPR) pushbutton on the flight control unit (FCU)[2] (Figure 1). Arming final approach mode sets the auto-flight system to capture and track the lateral and vertical final approach paths.

The crew slowed the aircraft to 250 kt nearing 5,000 ft to comply with a company speed restriction of 250 kt maximum below 5,000 ft. Passing about 4,200 ft, the auto-flight system sequenced to final approach mode and the crew set 3,000 ft in the FCU altitude window - the missed approach altitude associated with the RNP Y approach to runway 23L.[3]

Approaching 3,000 ft, the crew levelled the aircraft to further reduce speed by selecting 'PUSH TO LEVEL OFF' on the FCU. This speed reduction was required to comply with another company speed restriction of 210 kt maximum below 3,000 ft. Levelling the aircraft however, meant that the auto-flight system exited final approach mode – while still tracking the approach procedure laterally, the aircraft was no longer following the defined vertical approach path. Once the aircraft had slowed sufficiently, the crew resumed descent in managed descent mode, intending to allow the auto-flight system to continue descent and re-capture the vertical aspect of the final approach path. Immediately upon the resumption of the descent however, the auto-flight system captured and levelled the aircraft at 3,000 ft – the missed approach/go-around altitude previously set in the FCU altitude window.

Soon after altitude capture, the crew wound the FCU altitude window to 5,000 ft by rotating the altitude selector knob, then inadvertently pulled the altitude selector knob. This action caused the auto-flight system to engage in open climb mode[4] contrary to the intent of the crew which was to continue descent and resume the approach. In open climb mode, the auto-flight system (flight directors) commanded a climb to 5,000 ft – the altitude now set in the FCU altitude window. As engine thrust increased however, the FO initially maintained a shallow descent, having moments earlier disconnected the auto-pilot and assumed manual aircraft control. The combined effect of the increase in engine thrust and the shallow descent resulted in unwanted aircraft acceleration.

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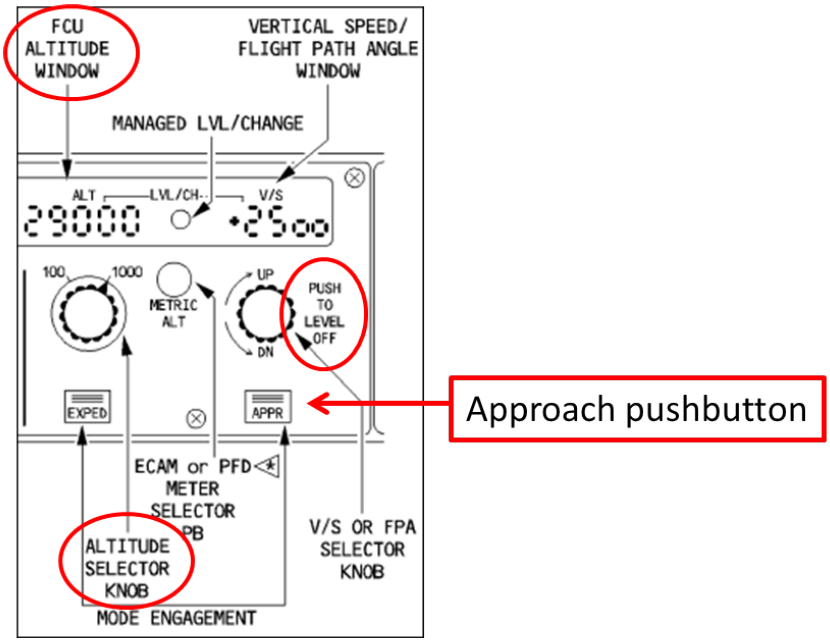
[1] RNP approaches involve following a defined lateral and vertical approach path. RNP approach procedures require the application of performance-based navigation specifications requiring specific standards of equipment and on-board navigation system monitoring capabilities.

[2] The FCU is located on the glare-shield and provides an interface between the crew and the flight management guidance computers. Among other things, different flight guidance modes and flight parameter targets such as speed and altitude can be selected on the FCU.

[3] The missed approach altitude is the altitude to which the aircraft is required to climb in the event that the approach is discontinued. In the operator's procedural documents dealing with auto-flight system management, this altitude is commonly referred to as the go-around altitude. The operator's RNP Crew Review Card procedures allowed the crew to set the missed approach/go-around altitude after the auto-flight sequenced to final approach mode.

[4] In open climb mode, the auto-flight system commands a climb to the altitude set in the FCU altitude window and the auto-thrust system sets climb thrust.

Figure 1: Relevant part of FCU panel (vertical control area)



Source: Airbus – highlights by ATSB

As the aircraft speed approached 230 kt (which was the maximum speed for the existing configuration),[5] the captain took control from the FO (continuing with manual control), retarded the thrust levers to the idle stop position and applied full speedbrakes.[6] Aircraft speed peaked momentarily at 230.7 kt, marginally above the 230 kt maximum speed for the existing configuration, but no over-speed warnings were triggered because the speed did not reach the over-speed warning activation threshold. By retarding the thrust levers, the captain reduced the maximum thrust available (to the auto-thrust system) and prevented what may have been a significant overspeed,[7] but in reaching the idle stop the captain inadvertently disconnected the auto-thrust system. A number of momentary alerts activated, intended to draw the attention of the crew to the disconnected status of the auto-thrust system, but none of these effectively captured their attention on this occasion.[8]

About 50 seconds after the captain took control, as the aircraft decelerated through about 180 kt, the auto-flight system re-captured final approach mode as intended, again tracking the lateral and vertical final approach paths. At about the same time, the crew selected the next stage of flap/leading-edge slat extension (configuration 2), retracted the speedbrakes and re-engaged the auto-pilot. Also at about this time, the captain handed aircraft control back to the FO, but the thrust levers remained at the idle stop, and neither pilot was aware that the auto-thrust system had been disconnected (and was therefore not controlling aircraft speed).

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5 The existing configuration was wing leading-edge slats at 18 degrees and flaps up (flap lever position 1).

6 The captain later commented that there was insufficient time to re-engage the auto-pilot and use the auto-flight system (speed selection) to prevent an over-speed, instead initiating a more prompt response by retarding the thrust levers and applying speedbrake.

7 With the auto-thrust system active, retarding the thrust levers has the effect of reducing the maximum thrust that can be applied by the auto-thrust system. When the thrust levers are set below the climb detent (with both engines operating), repeating alerts draw the crew's attention to the limited thrust condition.

8 When the auto-thrust system is disconnected using an instinctive disconnect pushbutton on the thrust levers or setting the thrust levers to the idle stop, a single chime aural warning sounds, the master caution light illuminates momentarily, and the Electronic Centralised Aircraft Monitoring system briefly displays an amber A/THR OFF message.

Soon after handing back control, the captain's attention was directed to flight path monitoring and ATC communications as the pilot monitoring (PM). Although somewhat surprised at the handover of aircraft control, the FO resumed control and shifted attention from PM duties to aircraft profile and configuration management as the pilot flying. As the approach progressed and the aircraft decelerated, the crew continued to configure the aircraft in preparation for landing, still unaware that the auto-thrust system was disconnected.

The crew commented that they were aware that the aircraft was decelerating as it was configured, but expected the thrust to increase as speed neared the approach speed. The captain believed that the auto-thrust system was still active when control was handed to the FO, but neither pilot could recall confirming operation of the auto-thrust system on their respective flight mode annunciators (FMA) at that time.[9] The FO commented that deceleration toward the approach speed appeared normal as the aircraft was being configured for landing.[10] At about the same time, the attention of the FO was beginning to shift to an external visual scan of the runway environment. Just as the final stage of flap/leading-edge slat was selected (flap lever to the FULL position), speed reduced through the approach speed of 136 kt and the lowest selectable speed (see later section titled *airspeed indicator*), which at that moment was 133 kt.

As the aircraft descended through about 1,700 ft and reached a speed of 120 kt, the flight augmentation computers[11] generated an aural low-energy 'speed speed speed' warning. The captain responded to the low-energy warning by again taking control from the FO, disconnecting the auto-pilot and advancing the thrust levers toward the climb detent. Despite thrust lever advancement, aircraft speed briefly and marginally continued to reduce given the inertia of the aircraft and the finite time required (albeit very momentary) for the engines to deliver a thrust output that corresponded to the increased thrust lever setting. The aircraft slowed through the alpha[12] protection speed of about 117 kt, followed almost immediately by engagement of the alpha floor auto-thrust mode at 116 kt (which was the minimum speed reached). The nature of the low-energy warning, alpha protection speed and alpha floor auto-thrust mode, are described later in the report.

The alpha floor auto-thrust mode automatically re-activated the auto-thrust system and initiated the application take-off/go-around (TOGA) thrust, even though the captain was manually advancing the thrust levers at the same time. The captain disconnected the auto-thrust system using the instinctive disconnect pushbutton on the thrust levers about 5 seconds after alpha floor mode engagement, thereby allowing the crew to establish manual thrust control[13] and accelerate the aircraft to the approach speed. At the moment the captain disconnected the auto-thrust system, the aircraft was accelerating through about 129 kt and descending through about 1,600 ft. Manual thrust management was retained for the remainder of the flight, which continued from that point to an uneventful landing. A selection of recorded data that graphically represents the occurrence is shown in Figure 2.

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9 Among other things, the FMA displays the status of the auto-thrust system, and the mode of auto-thrust system operation.

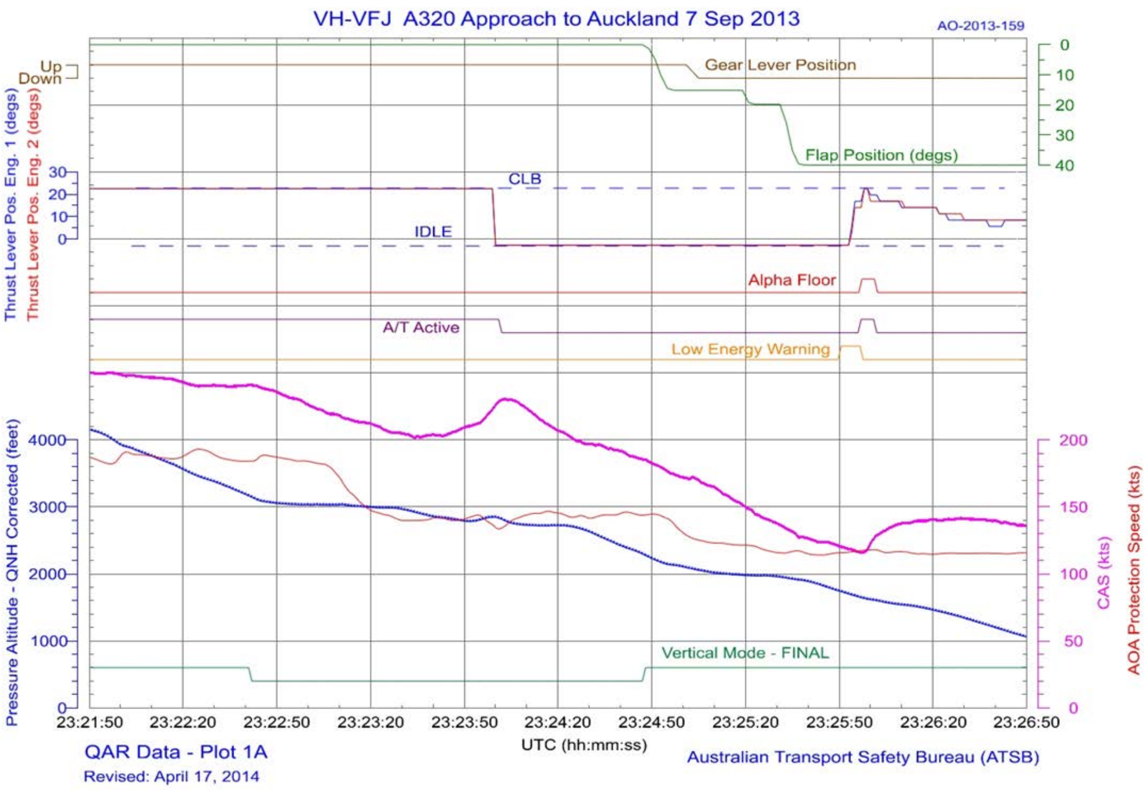
10 The FO indicated that the perception of aircraft deceleration toward the approach speed may have been influenced to some extent by an expectation that the auto-thrust system may not control deceleration accurately on this occasion. The FO had recently experienced less precise auto-thrust system speed control with this particular aircraft than was normally the case, although there was no entry in aircraft technical documentation to that effect.

11 The aircraft has two flight augmentation computers that perform a range of functions including yaw-related functions, flight envelope-related functions, and low energy warning and windshear detection functions.

12 Alpha refers to the angle-of-attack of an aircraft wing, measured as the angle between the wing chord line and the local undisturbed airflow. If alpha increases beyond a certain angle (commonly referred to as the stalling angle), the characteristics of the airflow over the wing change to the extent that the wing is said to have aerodynamically stalled. Broadly speaking, an aerodynamic stall typically results in a relatively sudden and substantial loss of lift.

13 If the auto-thrust system is not disconnected following engagement of the alpha floor auto-thrust mode, thrust increases to TOGA and remains locked at that thrust setting until crew intervention.

Figure 2: Quick access recorder data plot - selected parameters



Source: ATSB

Relevant warnings and flight envelope protection (normal law)[14]

Low-energy warning:[15] An aural low-energy 'speed speed speed' warning repeats at 5-second intervals to caution the crew that aircraft's energy state is below a threshold whereby increased thrust is required. Depending on the circumstances, the aircraft pitch attitude may also warrant adjustment. Activation of the low-energy warning is based on a number of parameters, including speed and rate of deceleration. During deceleration, the low-energy warning is triggered before alpha floor (unless alpha floor is triggered by stick deflection). The speed difference between the low-energy warning and triggering of the alpha floor auto-thrust mode depends on the rate of deceleration. During this incident, the low-energy warning activated at 120 kt, 4 kt before the alpha floor auto-thrust mode engaged.

High angle-of-attack protection: High angle-of-attack protection is intended to prevent an aerodynamic stall or loss of control. A320 high angle-of-attack protection includes the following:

- ***Alpha protection speed:*** Alpha protection speed corresponds to the angle-of-attack at which alpha protection activates. A number of things happen when alpha protection activates, including a change in flight control system pitch mode characteristics. Additionally, the

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14 The Airbus A320 incorporates fly-by-wire technology. Crew flight control inputs are transmitted to flight control computers, which command appropriate flight control surface movement. The laws governing operation of the flight control system are known as flight control laws. The flight control system usually operates in 'normal law', which provides a number of flight envelope protection functions, including high angle-of-attack protection. Under certain conditions, operation of the flight control system may degrade to 'alternate law' or 'direct law'. When control laws are degraded, high angle-of-attack protection may be replaced by artificial low speed stability or lost entirely, depending upon the extent of control law degradation.

15 The low-energy warning is only available with certain flap settings and is inhibited under some conditions. The conditions prevailing at the time of this incident did not inhibit the low-energy warning.

auto-pilot will disengage if the angle-of-attack reaches one degree above the angle-of-attack at which alpha protection activates. During this incident, the alpha protection speed was 117 kt, 1 kt above the minimum recorded speed of 116 kt.

- ***Alpha floor mode:*** Alpha floor is an auto-thrust mode designed to assist in recovery from a high-alpha, low-airspeed condition. Activation of alpha floor mode is dependent on a range of parameters, including rate of deceleration. Activation of alpha floor mode leads to the automatic application of TOGA thrust, regardless of the existing thrust lever position and status of the auto-thrust system. TOGA thrust is locked (TOGA LK appears on the FMA as the active auto-thrust mode) until the auto-thrust system is disconnected by the crew. Activation of alpha floor mode also generates an associated 'A. FLOOR' annunciation in green, surrounded by a flashing amber box, on the FMA. 'A. FLOOR' is also annunciated in amber on the electronic centralised aircraft monitoring system (engine warning display). During this incident, alpha floor mode engaged at the minimum recorded speed of 116 kt and remained engaged for about 5 seconds before disconnection of the auto-thrust system by the captain.
- ***Alpha max:*** Alpha max is the maximum angle-of-attack that can be attained in normal flight control law. The speed corresponding to alpha max is referred to as the alpha max speed. To prevent the onset of an aerodynamic stall, the flight control system will not allow alpha max to be exceeded, even if the control stick is pulled fully back. Alpha max speed was not a recorded parameter, nor was it reached during this incident.

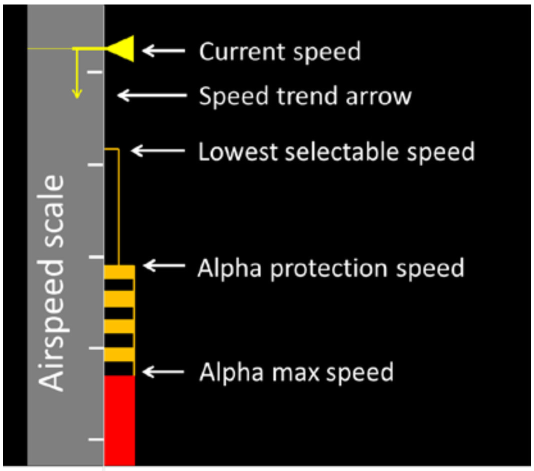
Airspeed indicator

The airspeed indicator is located on each pilot's primary flight display. In addition to current airspeed, the indicator includes references to predicted speed and high angle-of-attack protection speeds (normal law). Some relevant information includes (Figure 3):

- A speed trend arrow that indicates what the speed will be in 10 seconds at the current rate of acceleration or deceleration.
- Lowest selectable speed, which is the lowest speed that can be selected by the crew while maintaining a suitable margin above the aircraft stall speed.
- Alpha protection speed, represented by the top of an amber and black strip.
- Alpha max speed, represented by the top of a red strip.

Note that the speed at which the low energy 'speed speed speed' alert will sound and the speed at which alpha floor auto-thrust mode will engage are not depicted on the airspeed indicator.

Figure 3: Representation of primary flight display airspeed indicator low speed protection markings (normal law)



Source: ATSB

Operator's investigation findings

The operator conducted an internal investigation into the incident and made a number of findings, some of which are broadly summarised as follows:

- The operator found that there may be some commonly-held misunderstandings (by flight crew in general) regarding some aspects of instrument approach management procedures, particularly their application to RNP approaches. The operator's report included reference to procedures dealing with setting the missed approach/go-around altitude in the FCU altitude window, and the procedures related to capturing an approach path from above.
- The operator also made findings with respect to crew communication, aircraft energy state monitoring, wider automation management and mode awareness issues, and the procedures governing the reinstatement of aircraft control following intervention by the pilot not flying.

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 actions.

Operator

Since this occurrence, the operator has made a customised amendment the Flight Crew Operations Manual (FCOM) procedure with respect to the point at which the missed approach/go-around altitude may be set in the FCU altitude window during an RNP approach. Although the revised procedure was introduced for reasons not directly related to this incident, the amendment does address a procedural inconsistency between the FCOM and the operator's RNP procedure Crew Review Card that was identified by the captain following this incident.

As a result of this occurrence, the aircraft operator has advised the ATSB that a number of safety actions have been, or will be undertaken, including:

- Communication to all flight crew regarding relevant procedures for setting the missed approach/go-around altitude, with appropriate explanatory information.
- Communication to all flight crew regarding procedural requirements dealing with FMA awareness and speed monitoring.
- Flight Safety and Standards Committee consideration of the issues surrounding transfer of aircraft control, and wider automation management and mode awareness issues.
- Inclusion of guidance dealing with reinstatement of aircraft control (following control intervention by the other pilot) in appropriate documentation.

Safety message

To operators of highly automated aircraft, this incident highlights the importance of robust approach management procedures, and clear guidance dealing with associated management of aircraft auto-flight systems. Effective and comprehensive operational procedures that are clearly documented, well understood, regularly practised and consistently applied are fundamental to safe aircraft operations. The incident also highlights the need for clear procedural guidance regarding communication protocols following a transfer of aircraft control between pilots, particularly following intervention by the pilot not flying.

For flight crew, this incident highlights the importance of consistent attention to the status and mode of operation of the auto-thrust system, particularly following manipulation of the thrust levers. This incident also highlights the importance of consistent attention to aircraft energy state. With respect to aircraft energy state, a recent ATSB report (Aviation Research Report AR-2012-172 dated 01 November 2013) titled *Stall warnings in high capacity aircraft: The Australian context*, included the safety message:

> 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, especially during an approach on the limits of being stable.

A copy of ATSB Aviation Research Report AR-2012-172 is available on the ATSB website at www.atsb.gov.au/publications/2012/ar-2012-172.aspx.

Additionally, this incident serves as a reminder of the importance of effective crew communication, particularly following a disruption to the normal sequence of events.

General details

Occurrence details

Date and time:	07 September 2013 – 1126 NZST	
Occurrence category:	Incident	
Primary occurrence type:	Flight envelope protection event	
Location:	Near Auckland, New Zealand	
	Latitude: 37° 01.85' S	Longitude: 147° 53.04' E

Aircraft details

Manufacturer and model:	Airbus A320	
Registration:	VH-VFJ	
Operator:	Jetstar Airways	
Serial number:	5311	
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.