Australian Government
Australian Transport Safety Bureau

Tail strikes during landing involving Bombardier DHC 8 402, VH-QOT and VH-QOS

Brisbane Airport, Qld on 5 November 2013 and Roma Airport, Qld on 11 December 2013

Investigation

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Addendum

Page	Change	Date

Safety summary

What happened

On 5 November 2013 and 11 December 2013, two Dash 8-400 aircraft, registered VH-QOT and VH-QOS, were being operated by QantasLink on scheduled passenger flights from Roma to Brisbane and Brisbane to Roma, Queensland respectively. Both flights were crewed by a training captain, operating as pilot monitoring, and a trainee first officer, operating as pilot flying.

Although the two approaches utilised different flap settings, both were conducted using a propeller setting of 1,020 RPM. The early, initial and final stages of the approaches were unremarkable. Both training captains reported that as the aircraft approached the flare, they thought that the respective trainees had handled the approach well.

During landing, both trainees arrested the descent rate by raising the nose of the aircraft. In both cases the maximum pitch attitude was exceeded and the aircraft's tail contacted the runway. Each aircraft sustained impact and abrasion damage to the fuselage skin and buckling of internal structures in the area of the tail strike sensor.

What the ATSB found

The ATSB's found that in the last 50 ft of both approaches to land, the pilot flying did not manage engine power commensurate with their aircraft's declining energy state. This induced the pilot to pitch up in each case to control the descent rate and exceed the pitch angle limits.

The ATSB also identified that varied emphasis on the appropriate handling technique and pitch attitude awareness during first officer training did not assure consistent application of an appropriate landing technique in the Dash 8-400 aircraft.

Finally, the use of 15° of landing flap resulted in a margin of 1.9° between the nominal landing flare pitch angle and the tail strike angle. That compared with a margin of 3.9° when using 35° of flap and a typical margin for other transport aircraft of over 5°.

What's been done as a result

In response to these occurrences, QantasLink issued several flight operational bulletins that provided additional information and guidance to assist pilots manage engine power and pitch attitude during landing. In addition, the training provided to training captains has been modified and specific training for pitch monitoring and landing recovery has been incorporated into the cyclic simulator training and proficiency program.

QantasLink flight operations analysis for the 12 months following the introduction of the above safety actions showed a significant reduction in the number of high pitch attitude landing events.

Safety message

Dash 8 pilots are reminded of the inherent risk of tail strike during landing. While all Dash 8-type aircraft have pitch limitations, they are most restrictive on the -400 and -300 variants. Pitch attitudes in excess of 6° must be avoided.

Reducing engine power to idle during the landing flare can cause a sudden and unexpected increase in drag and reduction of lift. An excessive rate of descent during landing must be corrected by applying power. The temptation to control the decent rate by pitching up must be avoided.

Contents

The occurrences

VH-QOT

On 5 November 2013, a Bombardier Inc DHC-8-402 (Dash 8-400) aircraft, registered VH-QOT, was being operated by QantasLink on a scheduled passenger flight from Roma to Brisbane, Queensland. The flight crew comprised a training captain, operating as the pilot monitoring (PM)[1], and a trainee first officer (FO), operating as the pilot flying (PF).

The flight crew had signed on at their home base, Brisbane, at 1045 Eastern Standard Time[2] and were rostered to operate two Brisbane to Roma and return flights. The FO conducted the landing at Roma without incident using 35° of landing flaps (Flap 35).

The aircraft departed Roma for Brisbane at 1323 and a visual approach to runway 19 at Brisbane Airport was commenced at about 1420. The weather for the approach included a crosswind of 18 kt and the possibility of light windshear at about 200 ft above the ground. Fifteen degrees of landing flaps (Flap 15) and a propeller RPM of 1,020 (see the section titled *Landing configuration guidance*) were selected and the target approach speed was increased due to the prevailing wind conditions.

The captain reported that despite the strong crosswind, the approach to land was well handled. Both the captain and the FO recalled that the initial flare[3] led to a smooth/light touchdown and that the aircraft immediately became airborne again. The aircraft subsequently flew level at about 10 ft before settling onto the runway about 4 seconds later.

Engine power, which had been set to flight idle as the aircraft descended through about 10 ft during the initial flare, remained at flight idle through to the second touchdown. That touchdown included a bounce, during which the main landing gear was briefly unloaded. The pitch attitude during this period reached 7.5° nose-up and the aircraft landed at 1425.

After the second touchdown, which the crew described as a normal Flap 15 landing, the TOUCHED RUNWAY warning light illuminated. Believing the warning to be spurious, the crew contacted air traffic control who, after conducting a runway inspection, advised there was debris on the runway consistent with a tail strike.

VH-QOS

On 11 December 2013, the flight crew of a QantasLink Dash 8-400 aircraft, registered VH-QOS, signed on at their home base, Brisbane, at 1105. The crew, comprising a training captain and a trainee FO, was rostered to operate a return scheduled passenger flight from Brisbane to Emerald, Queensland, followed by a return flight to Roma.

The FO was the PF for the flight to Emerald and the captain was the PF for the return flight to Brisbane. The landing configuration used for those two landings was Flap 15 and a propeller RPM of 850.

The flight to Roma departed Brisbane at 1655. Prior to descent into Roma, the crew conducted an approach and a threat and error management briefing that discussed the intention to use Flap 35 and a propeller RPM of 1,020 for landing. The briefing also included a reminder not to retard the power too quickly as the use of idle with 1,020 RPM would create more drag than at 850 RPM.

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1 Pilot flying (PF) and pilot monitoring (PM) are 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 aircraft flight path.

2 Eastern Standard Time (EST) was Coordinated Universal Time (UTC) + 10 hours.

3 Final nose-up pitch of a landing aeroplane to reduce the rate of descent to approximately zero at touchdown.

The circuit and approach to land proceeded normally and the captain recalled that, as the aircraft passed through 50 ft, the FO had managed the approach well. At about 30 ft, and as the FO began to flare the aircraft to land, the captain observed the airspeed reducing and called for the FO to apply power. The airspeed reduce further and the aircraft contacted the runway firmly. The captain believed the engine torque at this time was about 20 per cent.

The FO reported being aware of the need not to reduce the power too quickly and was surprised by the captain's call for additional power. By the time the FO comprehended the intent of the call for more power, the aircraft had contacted the runway. Engine power had been set to flight idle during the flare and touchdown occurred at 1802. The pitch attitude immediately prior to touchdown was 8.4° nose-up.

Despite the firm landing, the captain believed it to be relatively normal and did not hear any unusual airframe noises. During the landing roll, the crew notice that the TOUCHED RUNWAY warning light was illuminated. The aircraft was taxied to the parking bay and after disembarkation, the crew visually confirmed that a tail strike had occurred.

Context

Flight crew information

Both training captains held an Air Transport Pilot (Aeroplane) Licence, a multi-engine command instrument rating and a valid Class 1 Medical Certificate. Both first officers (FO) held a Commercial Pilot (Aeroplane) Licence, a multi-engine command instrument rating and a valid Class 1 Medical Certificate. A summary of each pilot's aeronautical experience is listed at Table 1.

Table 1: Aeronautical experience summary

	VH-QOT		VH-QOS	
	Captain	First officer	Captain	First officer
Total flying hours	4,322	342	5,125	681
Hours in command	2,818	103	3,520	495
Hours on Dash 8 type	1,760	84	3,455	46
Hours on Dash 8-400	535	84	2,235	46
Hours in last 90 days	203	84	162	46
Hours in last 30 days		60		33

First officer of VH-QOT

The FO commenced training with QantasLink on 23 April 2013. The following 6 weeks comprised mainly induction and ground training and was completed by early June. That training was conducted with the majority of available days being utilised.

The FO conducted two of the required four fixed base procedural training sessions on 5 and 6 June 2013. That training was followed by an extended period of inactivity and the remaining two sessions were not conducted until 11 and 16 July 2013.

The FO's endorsement training, which consisted of 12 sessions in a flight simulator, commenced on 23 July 2013. That training included periods of inactivity and was not completed until 10 September 2013, a period of 50 days. Allowing for days off and rest, this endorsement training should typically take between 20 and 30 days to complete.

The FO's line training, conducted by a suitably-qualified training captain, commenced on 26 September 2013. The FO had completed 24 days of line training prior to the tail strike on 5 November 2013.

First officer of VH-QOS

The FO commenced ground training on 3 June 2013. The FO's training roster for June and the first 2 weeks of July included induction and ground training with most available days being utilised. For the remainder of July and up to late August, the pilot was on standby for 26 of the 30 available training days.

The FO commenced fixed base procedural training on 27 August 2013 and completed that training on 4 September 2013.

The FO's endorsement training commenced on 7 September 2013. That training, conducted during the remainder of September and all of October, included periods of inactivity and took 55 days to complete the stipulated 12 sessions.

The FO commenced line training on 5 November 2013. The FO had completed 13 days of line training prior to the tail strike on 11 December 2013.

Fatigue assessment

None of the operating crew members reported any fatigue concerns or health issues in relation to the occurrence flights.

The captain and FO of VH-QOT were on day 4 of a 5-day duty cycle. Both pilots reported being well rested and fit for duty. The current cycle was preceded by 2 days free of duty.

The captain and FO of VH-QOS had completed 10 days free of duty. Both pilots reported being well rested and fit for duty.

Aircraft information

Landing guidance

Bombardier Inc (Bombardier), the aircraft manufacturer, provided landing guidance in its Dash 8 aircraft operating and flight manuals. Normal landings could be conducted with any combination of 15° or 35° of landing flaps (Flap 15 or Flap 35) and a propeller RPM setting of 850 or 1,020. A preferred or optimal landing configuration was not specified.

In addition, a Bombardier pitch awareness video and service letter highlighted the length and susceptibility of the Dash 8-400 aircraft to tail strike as compared to the shorter fuselage variants. The video also detailed the:

- location of the possible rear fuselage tail strike area
- pitch angles at which the tail may contact the ground
- importance of pitch awareness and not exceeding 6° of nose-up pitch during landing
- typical approach to land pitch attitudes of about 0° to 1° nose up for Flap 15 and about 2° to 3° nose down for Flap 35
- attitude change during the flare to land of approximately 5° for both Flap 15 and Flap 35 approaches
- importance of controlling excessive rates of descent by increasing power rather than increasing the nose-up attitude near the ground. An increase in power increases the airflow over the wings directly behind the propellers and, therefore, increases lift even if the forward velocity does not change. If an excessive rate of descent close to touchdown cannot be corrected with power, a go around must be initiated.

Dash 8-400 touched runway indicating system

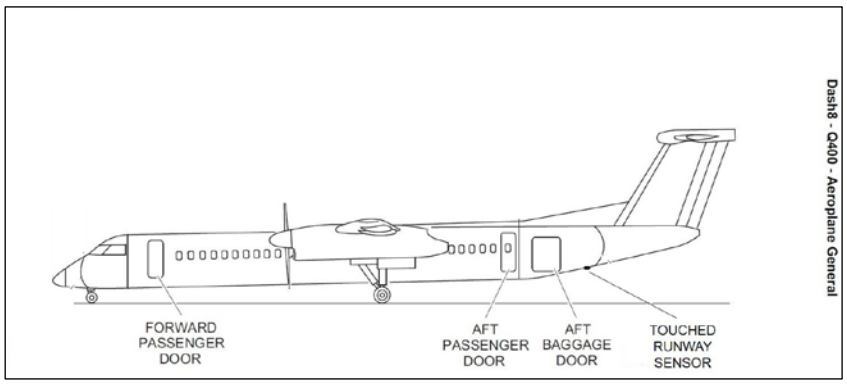
Most, if not all air transport aircraft have pitch limitations for take-off and landing in order to prevent the aft fuselage contacting the runway. Due to the design and length of the fuselage, the Dash 8-400 can experience tail contact on landing at pitch attitudes as low as 6.9°.

Additionally, due to reduced flare capability at lesser degrees of flap, there is a greater probability of aft fuselage/runway contact with landing flaps set at 15° than with flaps set at 35°.

The Dash 8-400 is fitted with a touched runway detection system that includes a frangible switch/sensor located on the underside of the aft fuselage (Figure 1). In the event of a tail strike, a TOUCHED RUNWAY warning light, located on the overhead warning light panel in the cockpit, illuminates.

At touchdown, depending on main gear oleo compression and curvature of the runway surface, tail contact will occur at between 6.9° and 7.5° nose up.

Figure 1: Touched runway detection system – sensor location

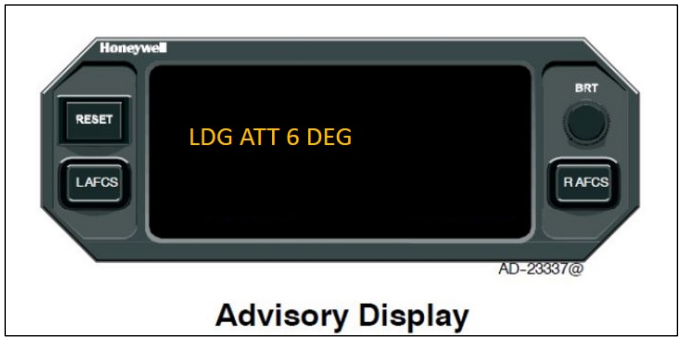


Source: Bombardier, modified by the ATSB

Dash 8-300 advisory display

The Dash 8-300 is fitted with an advisory display indicator (Figure 2), which is located in a prominent position on the captain's and FO's instrument panel. The four-line colour display shows operational, warning and caution messages including LDG ATT 6 DEG. This message advises flight crew that the landing attitude has reached the certification limit.

Figure 2: Dash 8-300 advisory display



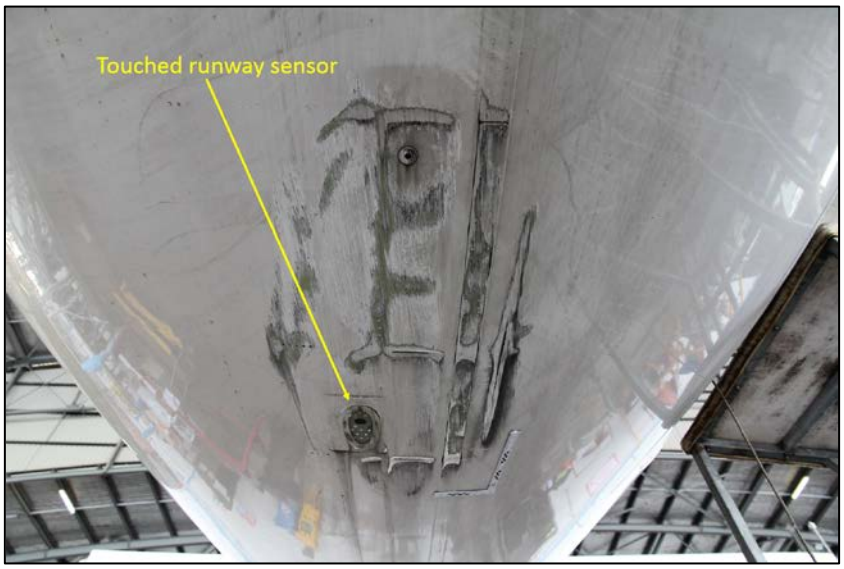
Source: QantasLink, modified by the ATSB

The Dash 8-400 is not fitted with an advisory display. Operational, warning and caution messages in the Dash 8-400 are displayed on the primary flight and navigation displays however, there is no caution message for landing attitude. The primary flight display is located on the pilot's instrument panel and includes an attitude indicator graduated in increments of 2.5°. During landing in the Dash 8-400, the monitoring pilot is required to monitor the attitude indicator and make advisory calls if the pitch attitude reaches 5° or 6°.

Aircraft damage

Both aircraft sustained impact and abrasion damage to the aft fuselage skin and buckling of internal structures in the area of the touched runway sensor (Figures 3 and 4).

Figure 3: Damage to the tail section of VH-QOT (looking aft)



Source: ATSB

Figure 4: Damage to tail section of VH-QOS (looking aft)

Source: ATSB

Flight recorders

Flight data recorder - VH-QOT

Analysis of recorded data indicated that the flare to land was commenced at about 20 ft. The airspeed at that time was 122 kt, slightly above the v_{ref}[4] of 119 kt for the approach but below the target approach speed (v_{app})[5] of 127 kt and engine torque about 10 per cent. Expected torque for a Flap 15 landing is about 17 per cent.

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[4] V_{ref} is the minimum speed at which a transport category aircraft complies with those handing criteria associated with approach and landing and is typically 1.3 times the aircraft's landing configuration stall speed.

[5] V_{app} is the approach target speed for a transport category aircraft and provides a speed margin over and above v_{ref} based on the prevailing local environmental conditions.

During the flare, due to the prevailing crosswind, the FO conducted a 'de-crabbing manoeuvre' to align the aircraft with the runway. Flight idle was selected as the aircraft descended through about 10 ft and the pitch attitude during the flare reached a maximum of 7.3°. The recorded data did not register ground contact associated with that flare. However, as the flight crew recalled that initial touchdown was very light, there may have been insufficient weight applied to the main landing gear sensor to record the initial runway contact. The aircraft floated just above the runway for a period of about 4 seconds during which time the airspeed reduced to 116 kt with no change in power. v_{ref} was 119 kt.

The pitch attitude at the second touchdown, which included a bounce as the main gear temporarily unloaded, was 7.5°. A data plot is included at appendix A.

Flight data recorder - VH-QOS

Analysis of recorded data indicated that between 100 ft and 30 ft, the airspeed reduced from 127 kt to 115 kt. The target approach speed was 120 kt and V_{ref} was 113 kt. Engine torque during this period was about 14 per cent, significantly below the expected torque for a Flap 35 landing of about 24 per cent.

The flare to land was commenced at about 30 ft and at about 10 ft, engine power was reduced to flight idle. Touchdown, which included a bounce as the main gear temporarily unloaded, occurred at an airspeed of 100 kt, 13 kt below the V_{ref} of 113 kt. The pitch attitude was 8.4° at that time. A data plot is included at appendix B.

Operator information

First officer training

General

Prior to commencing line operations, all FOs were required to complete the:

- QantasLink induction program
- Dash 8-400 ground engineering course and other mandatory ground courses, including viewing the Bombardier pitch awareness video
- Dash 8-400 endorsement program, which was conducted in the aircraft simulator.

The endorsement program comprised four fixed-base procedural training sessions and 12 full flight simulator training sessions. The final session included an assessment of the trainee's competency to progress to line training in the aircraft.

FO line training was conducted on revenue flights under the supervision of an appropriately-qualified training captain. FOs received between 75 and 100 hours of training followed by a check-to-line assessment.

First officers of VH-QOS and -QOT

The FOs of VH-QOS and VH-QOT reported that their simulator training was sporadic, due to a combination of simulator unserviceability and rostering. QantasLink identified a similar irregular training pattern with other trainee FOs due to extended periods of time being on-call to conduct training.

Pitch attitude awareness

The QantasLink Dash 8-400 flight crew operating manual (FCOM) highlighted that pilot awareness of pitch attitude during touchdown was essential to avoid a touched runway occurrence and cautioned against pitch attitudes in excess of 6°.

The aircraft typically requires a 5° attitude change during the landing flare. When landing with Flap 15, the approach attitude is close to zero so touchdown at around 5° nose up can be

expected. When landing with Flap 35 the approach attitude is around 2° nose down with touchdown at about 3° nose up.

The FCOM indicated that the pilot monitoring was required to note the pitch attitude during the landing flare and make a number of advisory calls if the pitch attitude reached 5° or 6° (Table 3).

Table 3: Pitch attitude advisory calls

Pilot monitoring	Pilot flying	Action
'Five degrees'	'Checked'	Check attitude and power and adjust if necessary, to avoid further increase.
'Pitch'	'Correcting'	Take immediate action to ensure pitch attitude does not exceed 6°.

The FCOM also stated that if the sink rate was too high during the roundout and flare, it was not to be corrected by pitching up beyond 6°. In such cases, an appropriate power increase could be used to further reduce the sink rate or, if necessary, a go around should be conducted.

Landing configuration guidance

At the time of the occurrences, QantasLink did not provide any landing configuration guidance or information additional to that provided by Bombardier. QantasLink did not specify a preferred or optimal landing configuration.

As detailed previously, normal landings could be conducted with any combination of Flap 15 or Flap 35 and a propeller RPM setting of 850 or 1,020. The selected landing configuration was at the discretion of the captain.

Flap 35 provides for a slower approach speed, reduced landing distances and a greater tail strike margin. Despite this, both training captains reported that most pilots preferred to use Flap 15 because the aircraft was more responsive, easier to handle and easier to land. Flap 35 was rarely used for other than training purposes.

A propeller RPM setting of 850 produces less noise in the cabin and less propeller drag. Reduced propeller drag lessens the aircraft's deceleration if the engine power is reduced to flight idle prematurely. In the event of a go around, propeller RPM will automatically increase to 1,020 RPM. An RPM of 1,020 provides increased sensitivity to power lever inputs and greater control over aircraft performance, and is therefore often used in windy or turbulent conditions.

Analysis of high pitch attitude events

About 5 months prior to these occurrences, QantasLink identified an emerging trend in high pitch attitude occurrences during landing. In response, a focused flight operations analysis was commenced, and remained ongoing, at the time of these occurrences.

In response to these two tail strikes, QantasLink re-analysed the data and identified an increasing trend of high pitch attitude landings conducted by FOs under training. That finding resulted in the implementation of a number of measures designed to reduce the risk of tail strikes (see the section titled *Safety actions*).

Information provided by QantasLink identified that, in the 12 months following the introduction of those safety measures, the number of high pitch attitudes during landing reduced significantly.

Previous similar occurrences

At the time of these occurrences, there had been 19 other tail strikes worldwide involving Dash 8-400 aircraft. Eighteen of these were during landing.

There have been two other previous tail strike occurrences involving Australian-registered Dash 8 aircraft. However, they involved earlier -100 or -200 series aircraft and appear to have been the result of wind-related environmental effects.

Safety analysis

Introduction

Due to its design and length, the Dash 8-400 has an increased risk of tail strike on landing that must be managed by the flight crew. The tail strikes that occurred on 5 November and 11 December 2013 took place when the affected aircraft were being flown by flight crew members under training. Both tail strikes were characterised by insufficient application of engine power and overpitching during the landing flare.

This analysis will discuss the development of the tail strikes, the operator's training and the risk controls in place at the time of the occurrences.

The tail strikes

While they had different flap settings, both approaches were conducted using a propeller RPM setting of 1,020. While that RPM setting resulted in higher overall drag compared to that associated with the alternate 850 RPM, the early, initial and final stages of the approaches were unremarkable. Both training captains reported that as the aircraft approached the flare, they thought that the respective trainee first officers (FO) had, as the pilot flying, handled the approach well.

The purpose of the flare is to reduce the rate of descent prior to touchdown. In the Dash 8-400, which has a relatively low tail strike attitude, the flare needs to be effected by careful use of pitch attitude change and engine power management.

In general terms, increasing the pitch attitude increases the lift generated by the wings and will therefore reduce the rate of descent. Due to the design of the Dash 8, the rate of descent can also be reduced by increasing engine power. Any increase in engine power will increase the airflow over the wing and produce additional lift. Conversely, reducing power to flight idle too early can result in a loss of lift and a significant increase in propeller drag, particularly when 1,020 RPM is used.

While not necessarily intuitive, a high sink rate during the flare must not be corrected in the Dash 8-400 by pitching up beyond 6°, as this could result in a tail strike. The correct response is to increase power or, if necessary, conduct a go around.

VH-QOT

The aircraft entered the landing flare at about the desired airspeed and with a power setting that was about 7 per cent lower than normal for the selected flap setting. Although the FO had to contend with a reasonably strong crosswind, the associated de-crabbing manoeuvre appears to have been well handled and not directly related to the tail strike.

During the flare, the sink rate was arrested by increasing the pitch attitude and power was reduced to flight idle as the aircraft descended through about 10 ft. The reduction of power to flight idle resulted in a loss performance and introduced a significant amount of propeller drag. Contrary to the recommended procedure, the rate of descent was reduced by further increasing the pitch attitude to 7.3°.

Following the initial flare and light touchdown, the pitch attitude was reduced to achieve level flight and the aircraft continued to float above the runway with idle power for about 4 seconds. The lack of engine power during this period resulted in a continued loss of performance that was instinctively countered by a further pitch attitude increase beyond the recommended 6° limit. This resulted in the tail contacting the runway.

VH-QOS

In the case of VH-QOS, the aircraft arrived at the flare with an already-decreasing airspeed and insufficient engine power. These conditions were symptomatic of insufficient performance for the stage of flight. Reducing engine power to flight idle during the flare further reduced the aircraft's performance and introduced a significant amount of propeller drag.

The inadequate performance, significant propeller drag and additional drag associated with Flap 35 resulted in the airspeed reducing rapidly from 115 kt to 100 kt. While the corresponding loss of lift should have been countered by an increase in engine power, the FO intuitively pitched up further. At touchdown, the airspeed was 13 kt below the minimum airspeed and the pitch attitude was 8.4°.

Conclusion

The selection of flight idle during the landing flare, possibly aggravated by the increased drag associated with a propeller setting of 1,020 RPM, resulted in a significant loss of performance that was incorrectly countered by the respective FO by increasing the aircraft's pitch attitude.

In both cases, the FO did not manage the engine power commensurate with the aircraft's declining energy state, inducing them to inadvertently pitch up to control the descent rate and exceed the aircraft's pitch angle limit.

Endorsement training

QantasLink's identification of an emerging trend in high pitch attitude landings prior to these occurrences highlights the value of analysing flight operations data. The resulting focus on data analysis, while not preventing these occurrences, was a proactive response by QantasLink.

Additional analysis of flight operations data by QantasLink following these two occurrences identified an emerging trend of high pitch attitude occurrences during landing among the trainee FOs. There was a significant reduction in the number of these occurrences in the 12 months following the introduction of safety measures. These measures included:

- additional landing guidance
- additional training captain guidelines
- the implementation of pitch- and landing-focused simulator/line training programs.

This supports the conclusion that the occurrences took place as a result of inadequate landing techniques and pitch attitude awareness deficiencies among those FOs.

Simulator training, both endorsement and recurrent, can be a very powerful and effective training aid. The endorsement training for the FOs that were involved in these two occurrences included minimal normal landings and did not include any specific training to address the risk of tail strike. Had the syllabus included simulator training to reinforce the correct procedure for reducing higher-than-normal descent rates on approach and pitch awareness, the tail strikes may not have occurred.

Both FOs reported that their training was conducted over an extended period of time with periods of inactivity between simulator sessions. QantasLink identified that the training schedule for other recently-employed FOs exhibited similar patterns and in some cases took even longer to complete. Such sporadic training may not provide trainees with adequate opportunity to consolidate and retain newly-learned skills. However, as the content of the training did not adequately prepare the FOs to land the Dash 8-400 aircraft, it is difficult to assess whether the irregular training pattern may have, in isolation, influenced the development of these occurrences. The potential for the irregular training to have compounded any difficulties experienced by the FOs during their training could not be discounted.

Risk controls

Pitch monitoring

The operator's procedures required the pilot monitoring to make 5° and 6° pitch attitude calls. However, on both occurrences the pitch attitude went from an acceptable attitude to over 7° in a very short period of time. Given that both flying pilot FOs were under training, it is likely that the training captain's focus in each case was directed more towards the manipulation of the aircraft rather than the existing pitch attitude.

In the case of VH-QOT, the pitch attitude during the initial flare changed from 3.2° to 7.3° in 2 seconds. There may have been an opportunity for the captain to notice and call the excessive pitch attitude during the 4 second float. However, it appears their focus was more towards ensuring the aircraft settled onto the runway than its pitch attitude.

In the case of VH-QOS, the pitch attitude changed from 1.2° to 8.4° in 1.5 seconds. During this short period the captain called for the FO to add power to arrest the rapidly-reducing airspeed. The situation developed so rapidly that there was insufficient time for the captain to recognise and make the required pitch attitude calls.

Earlier versions of the Dash 8 are fitted with an advisory display that provides a visual caution when the pitch attitude reaches 6°. The display is located in a prominent position and, if fitted to the occurrence aircraft, may have been of assistance in bringing the high pitch attitude to the attention of the crew. However, given how quickly the situations developed, it seems unlikely that a similar caution would have proved effective in preventing these tail strikes.

Landing flap selection

Most air transport aircraft use flap settings of about 30° or greater for landing. Those settings provide for tail strike margins in excess of 5°. Despite the operational benefits of using Flap 35, full flap on the Dash 8-400, flight crew appear to prefer the use Flap 15 due to the aircraft being more responsive, easier to handle and easier to land. While the use of Flap 15 does provide a performance benefit in the event of a go-around, none of the airports to which QantasLink operated required its use.

While flight crews may prefer the use of Flap 15 for landing, the margin between a normal approach attitude and tail strike attitude in that configuration is reduced from about 4° to about 2°.

Findings

From the evidence available, the following findings are made with respect to the tail strike occurrences involving Dash 8-400 aircraft, registered VH-QOT, at Brisbane Airport, Queensland on 5 November 2013 and Dash 8-400 aircraft, registered VH-QOS, at Roma Airport, Queensland on 11 December 2013. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

Contributing factors

- In the last 50 ft of both approaches to land, the first officer, who was the pilot flying, did not manage engine power commensurate with the aircraft's declining energy state, inducing the first officer to inadvertently pitch up to control the descent rate and exceed the pitch angle limits.
- Varied emphasis on the appropriate handling technique and pitch attitude awareness during first officer training did not assure consistent application of an appropriate landing technique in the Dash 8-400 aircraft.

Other findings

- The use of Flap 15 for landing results in a margin of 1.9° between the nominal landing flare angle and the tail strike angle, compared to a margin of 3.9° when using Flap 35 and a typical margin for other transport aircraft of over 5°.
- About 5 months prior to these occurrences, QantasLink identified an emerging trend in high pitch attitude occurrences during landing. In response, a focused flight operations analysis was commenced, and was ongoing, at the time of these occurrences.

Safety issues and actions

The ATSB did not identify any organisational or systemic issues that might adversely affect the future safety of aircraft operations. However, 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.

Proactive safety action taken by QantasLink

In response to the tail strikes, QantasLink made a number of changes to their training procedures including:

- changes to training captain selection criteria and to the training provided to training captains
- amendments to training captain proficiency lesson plans to include pitch attitude monitoring, dedicated training to raise awareness of potential candidate errors and intervention/recovery training
- implementation of a pitch attitude monitoring and landing recovery training session as part of the cyclic simulator training and proficiency program
- implementation of a new rostering protocol that, where a first officer's training is disrupted by a period of more than 7 days, they will receive additional training events.

QantasLink also issued several flight operational bulletins that:

- provided additional information and guidance on landing techniques covering the approach to land, flare, and appropriate use of engine power
- cautioned that reducing power to idle close to the ground or in the flare may cause a sudden and unexpected increase in drag along with a reduction of lift
- cautioned that should a higher-than-normal decent rate be experienced during the landing phase, the temptation to control this decent rate by pitching up must be avoided
- required all flight crew to review the pitch awareness video by a set date
- reminded flight crew of the standard pitch awareness calls and associated actions
- provided guidance for bounced and skipped landing recovery
- placed restrictions on the use of 1,020 RPM for landing.

Those bulletins have subsequently been incorporated into QantasLink's operations manuals.

Proactive safety action taken by Bombardier Inc

On 21 September 2016, Bombardier Inc advised that, following a review of the landing guidance provided in their pitch awareness video, they were in the process of amending the associated Flight Operations Service letter to include the following:

> **PURPOSE**
>
> This Flight Operations Service Letter is issued to provide landing guidance for Tailstrike Avoidance on the Q400
>
> **DISCUSSION**
>
> There have been a number of tailstrikes recently resulting in damage to the aft lower fuselage.
>
> The Aircraft Flight Manual (AFM) is the only approved document with respect to flight management of the aircraft.
>
> Bombardier wishes to remind Operators to be mindful of aircraft pitch attitude during the flare (the following extracted from Section 4.4 of the AFM)

NOTE

1. **To decrease the landing descent rate and not exceed a pitch attitude of 6°, when the landing descent rate is higher than desired, power will be required in the landing flare through to touchdown.**
2. **To decrease the landing descent rate at airport altitudes greater than 5,000 ft, it may be necessary to maintain power in the landing flare through to touchdown.**

CAUTION

Pitch attitudes greater than 6° in the landing flare may cause the fuselage to contact the runway.

A Pitch Awareness Training video was developed as general guidance to avoid aft lower fuselage contact during the landing and should be considered as examples of approaches and landings. A nominally flat pitch attitude should be expected for flap 35°, while a flap 15° approach will be flown slightly nose-up, when the appropriate V_{REF} speed is adhered to.

While some Q400 operational tailstrikes have included unstable approaches, all Q400 tailstrikes during the landing flare occurred as a result of not respecting the AFM Caution of 6° during the landing flare.

It is important to focus attention on speed management during the approach, which in turn will allow the aircraft to stabilize the appropriate pitch attitude. As each approach for landing can be subtly different, so can the pitch attitude. Management of the absolute pitch attitude during the landing flare to less than 6° at touchdown, as well as increasing power to reduce the sink rate will help flight crew avoid tailstrikes.

General details

Occurrence details VH-QOT

Date and time:	5 November 2013 – 1425 EST
Occurrence category:	Incident
Primary occurrence type:	Ground strike
Location:	Brisbane Airport, Queensland

Occurrence details VH-QOS

Date and time:	11 December 2013 – 1800 EST
Occurrence category:	Incident
Primary occurrence type:	Ground strike
Location:	Roma Airport, Queensland

Aircraft details VH-QOT

Manufacturer and model:	Bombardier Inc Dash 8-400
Operator:	Sunstate Airlines (Qld) Pty Ltd trading as QantasLink
Serial number:	4269
Type of operation:	Air Transport High Capacity
Damage:	Minor

Aircraft details VH-QOS

Manufacturer and model:	Bombardier Inc Dash 8-400
Operator:	Sunstate Airlines (Qld) Pty Ltd trading as QantasLink
Serial number:	4263
Type of operation:	Air Transport High Capacity
Damage:	Minor

Sources and submissions

Sources of information

The sources of information during the investigation included the:

- flight crew of VH-QOT and VH-QOS
- flight data recorders of VH-QOT and VH-QOS
- QantasLink
- Bombardier Inc.

Submissions

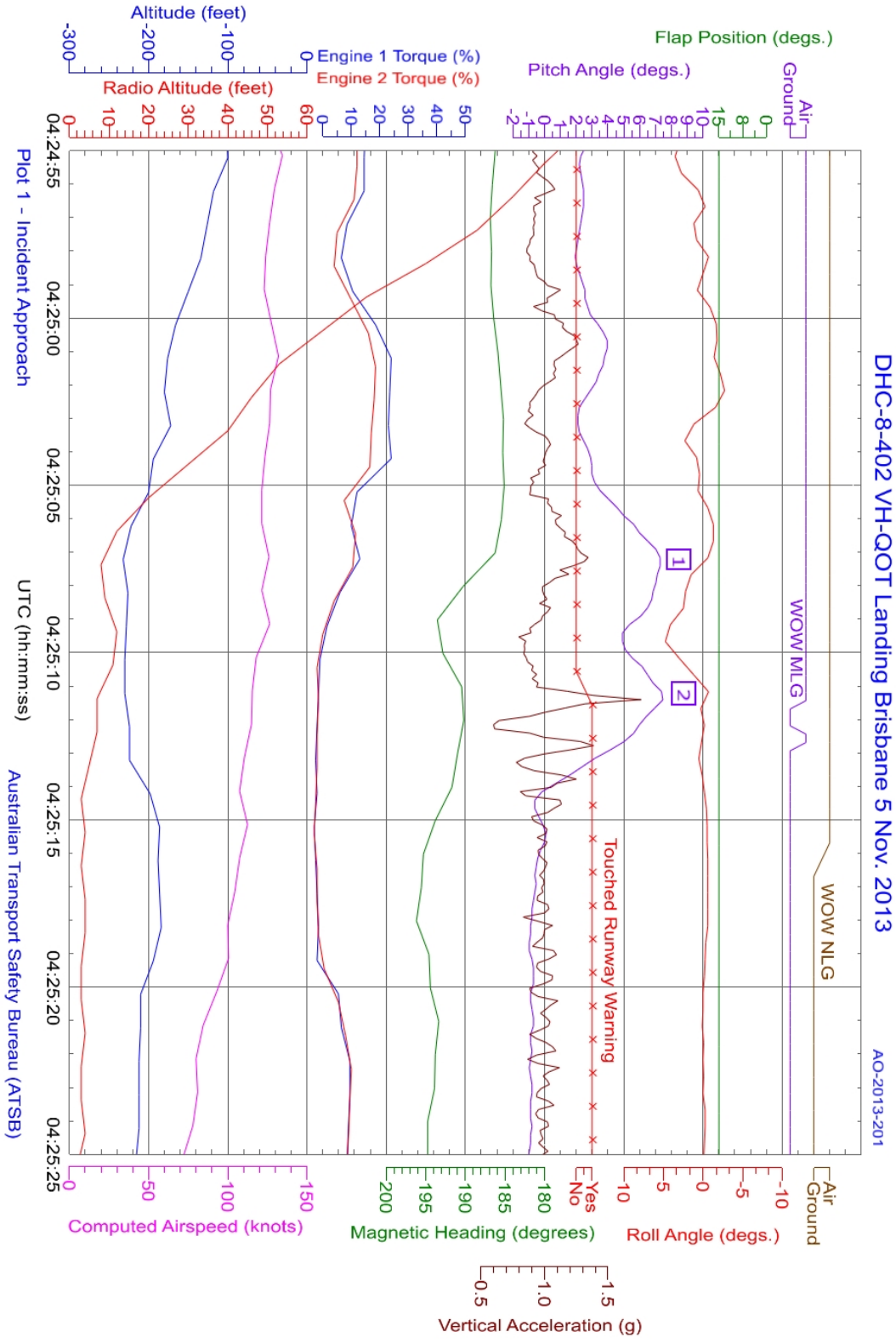
Under Part 4, Division 2 (Investigation Reports), Section 26 of the *Transport Safety Investigation Act 2003* (the Act), the ATSB may provide a draft report, on a confidential basis, to any person whom the ATSB considers appropriate. Section 26 (1) (a) of the Act allows a person receiving a draft report to make submissions to the ATSB about the draft report.

A draft of this report was provided to the flight crew of VH-QOT and VH-QOS, QantasLink, Bombardier Inc, the Transportation Safety Board of Canada and the Civil Aviation Safety Authority.

Submissions were received from a flight crew member of VH-QOT, QantasLink, Bombardier Inc and the Civil Aviation Safety Authority. The submissions were reviewed and, where considered appropriate, the text of the draft report was amended accordingly.

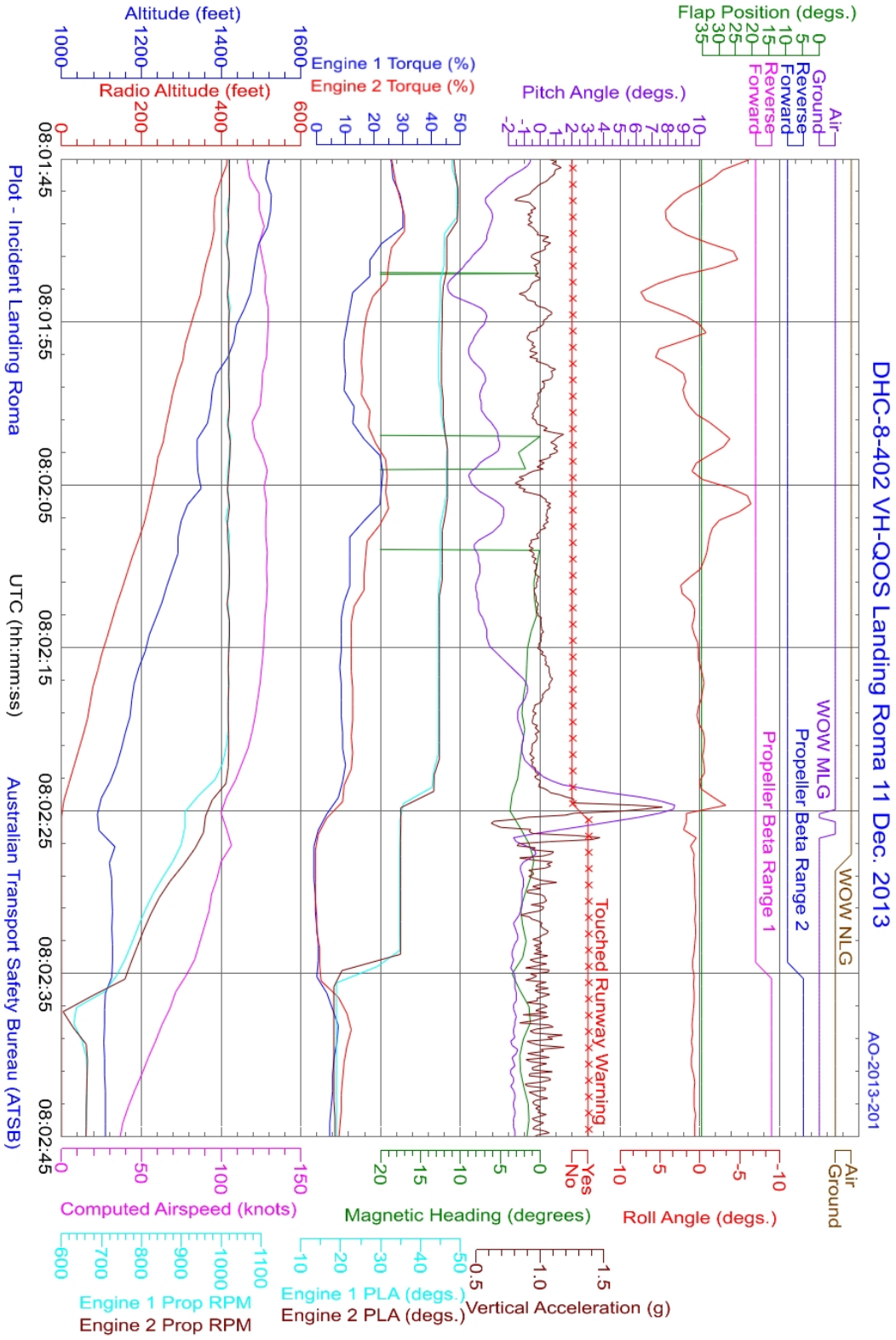
Appendices

Appendix A – VH-QOT approach and landing data



Source: ATSB

Appendix B – VH-QOS approach and landing data



Source: ATSB

Australian Transport Safety Bureau

The 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.

Australian Transport Safety Bureau

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Notifications 1800 011 034
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Investigation

ATSB Transport Safety Report
Aviation Occurrence Investigation

Tail strikes during landing involving Bombardier DHC 8 402, VH-QOT and VH-QOS Brisbane Airport, Queensland, 5 November 2013 and Roma Airport, Queensland, 11 December 2013

AO-2013-201
Final – 28 October 2016