Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT A15O0015

Impact with terrain on approach

Jazz Aviation LP (dba Air Canada Express)
de Havilland DHC-8-102, C-GTAI
Sault Ste. Marie, Ontario
24 February 2015

Canada

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Aviation Investigation Report A15O0015

Cat. No. TU3-5/15-0015E-PDF
ISBN 978-0-660-07819-9

This report is available on the website of the
Transportation Safety Board of Canada at www.tsb.gc.ca

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Summary

The Jazz Aviation LP de Havilland DHC-8-102 (registration C-GTAI, serial number 078) was operating as flight JZA7795 on a scheduled flight from Toronto/Lester B. Pearson International Airport, Ontario, to Sault Ste. Marie Airport, Ontario. At 1825 Eastern Standard Time, while on approach to Runway 30 in conditions of twilight and reduced visibility due to blowing snow, the aircraft touched down approximately 450 feet prior to the runway threshold. Following touchdown, the aircraft struck one of the runway approach lights before coming to a stop approximately 1500 feet past the threshold, on the runway surface. There were no injuries to the passengers or to the crew; however, there was significant damage to the aircraft.

Le présent rapport est également disponible en français.

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1.0 Factual information

1.1 History of the flight

The Jazz Aviation LP (Jazz) de Havilland DHC-8-102 (registration C-GTAI, serial number 078) was operating as flight JZA7795 on a scheduled flight from Toronto/Lester B. Pearson International Airport (CYYZ), Ontario, to Sault Ste. Marie Airport (CYAM), Ontario.

On board the aircraft were 15 passengers, 2 flight crew members, and 1 cabin crew member. The captain performed the role of pilot flying (PF) and the first officer performed the role of pilot monitoring (PM).

Just prior to descent from cruise altitude, the PF briefed the PM for the expected approach into CYAM. The PF was aware of the marginal weather conditions and included the possibility of a go-around and diversion in the briefing.

As part of the briefing, the flight crew set the approach speed bugs[1] to the appropriate speed for aircraft weight and flight conditions. The crew determined that the applicable landing reference speed (Vref)[2] was 96 knots, which required an approach speed bug setting of 101 knots.

When the aircraft was approximately 42 nautical miles (nm) from CYAM, the controller at the Toronto Area Control Centre cleared the flight to descend to 5000 feet above sea level (ASL) and, given the expected weather conditions, requested that the crew report when they had the airport in sight for the visual approach.

As JZA7795 reached 15 nm from CYAM in level flight at 5000 feet ASL, the crew reported that the in-flight visibility was reduced due to ice crystals. In consideration of this, they requested to be cleared for the VOR/DME[3] approach to Runway 30, rather than the visual approach, and were cleared as requested.

While descending out of 3000 feet ASL, the flight crew passed through the area of ice crystals and acquired the airport visually. Although the flight was now in visual conditions, the crew noticed a significant snow shower approaching the arrival runway from the west. They reported these conditions to the controller, who cleared the flight for the visual approach, instructing them to deviate as necessary from the VOR approach.

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1 Speed bugs are a set of pilot-movable markers on the airspeed indicators that serve as a visual reminder.

2 Vref refers to the approach speed at a height of 50 feet above the runway in the landing configuration.

3 VOR/DME refers to very high frequency omnidirectional range / distance measuring equipment.

At 1821:34,[4] the aircraft passed over the final approach fix,[5] 8.7 nm from the runway threshold, at a height of 2840 feet above ground level (AGL)[6] and an indicated airspeed of 204 knots. The aircraft was descending on a 3° vertical path, although this was done visually, rather than with avionics-based vertical navigation guidance.

Between 1821:34 and 1823:05, the aircraft slowly decelerated from 204 to 181 knots while maintaining the 3° vertical path in descent from 2840 feet to 1500 feet.

At 1822:50, when JZA7795 was 5 nm from CYAM, the flight crew contacted the CYAM control tower for landing clearance. The controller informed the crew that the wind was from 310° magnetic (M) at 22 knots with gusts to 29 knots, and mentioned the line of weather currently rolling across the runway. The controller further informed the crew that, due to this weather, the runway visual range (RVR) visibility[7] had decreased to 1100 feet, with the runway lights set to level 4 intensity.[8] The PM responded that they could see the approaching weather.

At 1823:05 and at 1500 feet, the power levers were moved toward flight idle and the engine torque reduced to between 3% and 4%. The aircraft began to decelerate more rapidly.

At 1823:14, the tower controller informed JZA7795 that the RVR had now reduced to 1000 feet, with the runway lights now at level 5 (full) intensity. Wind was reported as from 310°M at 25 knots, and JZA7795 was cleared to land.

At 1823:49, at 1000 feet and 2.8 nm from the runway threshold, the flaps were extended to 15° and the PF increased torque to 25%. The aircraft's airspeed was 148 knots.

Between 1000 feet and 500 feet on approach, the aircraft generally maintained the 3° vertical path as the speed decreased from 148 to 122 knots. The engine torque varied during that time between 5% and 30% to account for configuration changes and wind gusts.

At 1824:33 and at 500 feet, the airspeed was 122 knots, or 21 knots higher than the bugged approach speed of 101 knots. The aircraft was on the appropriate vertical path and torque was steady at 25%. The PF made the 8° left turn to align the aircraft with the runway heading.

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4 All times are in Eastern Standard Time (Coordinated Universal Time minus 5 hours).

5 Final approach fix is defined as "the fix of a non-precision instrument approach procedure (IAP) where the final approach segment commences." Transport Canada, "Glossary for Pilots and Air Traffic Services Personnel."

6 From this point forward in the report, all heights are in feet above ground level (AGL), unless otherwise noted.

7 For Runway 30 at CYAM, the runway visual range (RVR) is measured by a transmissometer located near the western end of the runway.

8 The intensity of the airport lighting system is adjustable by the tower controller and ranges from 1 to 5, with 5 being the brightest.

At 1824:56, air traffic control (ATC) provided one last update to JZA7795, stating that the RVR was now 1200 feet.

At 1825:02, at 200 feet and at an airspeed of 124 knots, the PF began to reduce torque to idle and, as a result, the airspeed began to decrease rapidly. Although the aircraft's nose-up pitch was gradually increased and vertical speed was relatively stable, the vertical path steepened due to the decreasing airspeed and resultant ground speed reduction. The aircraft drifted below the 3° vertical path. This would normally be visually indicated by 4 red lights on the precision approach path indicator (PAPI), meaning the aircraft is too low.[9]

At some point below 200 feet, the flight crew lost visual reference to the ground due to the approaching weather system of blowing snow. The approach was continued.

At 1825:15, the terrain awareness and warning system (TAWS) issued a verbal alert to the pilots indicating that the aircraft's height was 50 feet.

At 1825:17 and at 20 feet, torque was increased toward 30%.

At 1825:19, the aircraft contacted the ground approximately 450 feet prior to the runway threshold at an airspeed of 94 knots.

The ground preceding the runway was covered in approximately 8 to 12 inches of snow.

The aircraft was in a level pitch attitude when it contacted the surface and touched down with a peak vertical acceleration of 2.32*g*.

Following touchdown, the nose landing gear assembly and wheel struck and damaged an approach light located 300 feet prior to the runway threshold. The flight crew heard a thump, but had not seen the light and were unsure what had caused the noise.

The aircraft came to a stop on the runway centreline, approximately 1500 feet past the threshold. The flight crew assessed the ground visibility as very poor, due to the blowing snow.

Unsure of the aircraft's status, the flight crew informed the tower controller that the aircraft may have landed short of the runway and may have clipped the nosewheel. The crew asked the control tower to send a vehicle to their position to assess the situation, and requested that a bus be sent to move the passengers.

When the emergency vehicles arrived and assessed the condition of the aircraft, no significant damage was noticed. Upon receiving this information, the flight crew elected to taxi the aircraft to the gate.

The aircraft taxied to the gate without further incident, and the crew shut down the engines and deplaned the passengers.

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9 *Transport Canada Aeronautical Information Manual*, Section AGA 7.6.3.

The crew did not believe there was damage to the aircraft and, therefore, did not pull the circuit breaker to prevent the cockpit voice recorder data from being overwritten. As a result, relevant data that would have been captured on the 30-minute cockpit voice recorder was overwritten while the aircraft remained electrically powered at the gate.

After exiting the aircraft at the gate, the crew was notified of damage to an approach light and contacted maintenance to have the aircraft inspected.

1.2 Injuries to persons

There were no reported injuries to the crew or the passengers on board.

1.3 Damage to aircraft

The aircraft sustained significant damage, mostly localized to the area near the nose landing gear, which had struck the approach light.

The nose gear and nose gear doors were damaged and required replacement. Additionally, both main landing gear were determined to have exceeded load limits and required replacement.

1.4 Other damage

The omnidirectional approach lighting system light located 300 feet east of the runway threshold, which was struck by the aircraft's nose gear, was damaged beyond repair.

1.5 Personnel information

1.5.1 Qualification

Records indicate that both flight crew members were certified and qualified for the flight in accordance with existing regulations.

1.5.2 Experience

The captain had been employed by Jazz for 17 years and had accumulated over 12 000 hours of total flight time, including 9000 hours flying Jazz DHC-8s.

The first officer had been employed by Jazz for 2 years and had 6630 hours of total flight time, with over 1300 hours on Jazz DHC-8s.

1.5.3 Training

Both flight crew members had received recurrent simulator training in November 2014.

The recurrent training syllabus included practising rejected landing and missed approach procedures following loss of visual cues at 100 feet. Both pilots completed this training syllabus without recorded difficulty, although neither could remember the specifics of the rejected landing training event.

Although the Jazz 2014–2015 simulator training cycle included training for pilots to recognize an unstable approach and initiate a go-around, the crew members had not completed this training before the occurrence.

1.5.4 *Scheduling and rest*

A fatigue-based analysis of the pilots' schedules was completed. It was determined that it was unlikely that fatigue was a factor for either flight crew member.

1.6 *Aircraft information*

1.6.1 *DHC-8-102 operating characteristics*

The approach speeds for the DHC-8-102 recommended in the *Jazz DASH 8 AOM Volume 2: Aircraft Operating Manual* (AOM) are among the slowest for all commonly used airliners operating within Canada under Subpart 705 of the *Canadian Aviation Regulations* (CARs).

Given that these aircraft frequent high-density airports, this presents a challenge for ATC when arriving DHC-8-102s are mixed with faster traffic on approach. Reducing the approach speed of the faster traffic is often not possible because most are already near minimum. Therefore, in an effort to keep the traffic orderly and expeditious, controllers will request, when necessary, that DHC-8-102 flight crews maintain higher speeds on initial approach.

The AOM instructs Jazz DHC-8-102 pilots to consider these requests when a stabilized energy state on approach is assured.

1.6.2 *Terrain awareness and warning system*

The aircraft was equipped with a Universal Avionics Systems Corporation TAWS unit.

To alert pilots to the aircraft's proximity to the ground during approach, the TAWS issues verbal announcements of the height above ground at numerous intervals during descent: at 500, 100, 50, 40, 30, 20, and 10 feet.

Following this occurrence, the flight crew could not recall hearing the automated verbal callouts during the event. Examination of digital data logged within the TAWS unit confirmed that no callouts were made below 50 feet.

It was determined that, by design, the unit will not trigger new callouts if it is already busy with another callout. Because only 5 seconds elapsed below 50 feet on the occurrence flight, it is likely the callouts did not occur; that is, there was not enough time for them to be made given the rapid rate of closure with the ground.

No previous or subsequent flight crews who operated the aircraft with the unit installed made any record of unusual operation.

1.7 Meteorological information

The forecasted weather for the planned time of arrival at CYAM called for generally good conditions, although a temporary condition of visibility reduced to 3 statute miles (sm) in light snow showers was forecasted between 1800 and 2300.

En route to CYAM, the flight crew received weather updates on the aircraft communications addressing and reporting system. These updates described the weather at CYAM as mostly good, with a visibility of 15 sm in drifting snow.

While JZA7795 was on final approach, 2 aerodrome special meteorological reports (SPECI) detailing the rapidly deteriorating weather conditions were issued. The SPECI issued at 1822 indicated that the ceiling was reduced to 2000 feet and visibility was reduced to 1 sm. The SPECI issued at 1824 indicated that the ceiling was further reduced to 300 feet and visibility was reduced to ¼ sm.

Although JZA7795 received RVR visibility updates from ATC during the final approach, given the time of their issuance, these SPECIs were not received by the flight crew prior to landing.

At CYAM, the sun set at 1816 and the amount of light gradually decreased until the end of evening civil twilight,[10] when night officially began at 1846.

1.8 Aids to navigation

The investigation did not identify any deficiencies in radio-based navigation aids.

1.9 Communications

The investigation did not identify any deficiencies in communications.

1.10 Aerodrome information

Runway 30 at CYAM is 6000 feet long by 200 feet wide.

For night operations, the runway is equipped with the following:

- high-intensity runway edge lighting;

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10 Evening civil twilight is defined as "relative to the standard meridians of the time zones, the period of time that begins at sunset and ends at the time specified by the Institute of National Measurement Standards of the National Research Council of Canada. Note: Evening civil twilight ends in the evening when the centre of the sun's disc is 6 degrees below the horizon." Transport Canada, "Glossary for Pilots and Air Traffic Services Personnel."

- threshold and runway end lighting;
- PAPI lights; and
- an omnidirectional approach lighting system.

The PAPI consists of 4 lights located on the left-hand side of the runway in the form of a wing bar. When the 2 units nearest the runway edge appear red and the remaining 2 appear white, the aircraft is on the nominal 3° approach slope. At an approach slope of 3.5° or above, all 4 light units will appear white (too high), whereas at an approach slope of 2.5° or below, all 4 light units will appear red (too low). The PAPI lights at CYAM are located 1100 feet from the runway threshold.

The crew of a flight that arrived 2 hours after the occurrence informed ATC that 1 of the 4 PAPI lights was obscured due to snow accumulation. The occurrence flight crew did not recall the PAPI being obscured during the incident approach.

1.11 Flight recorders

1.11.1 Data from the occurrence flight data recorder

The TSB recovered the flight data recorder (FDR)[11] from the aircraft and examined the data from the occurrence flight. Several disparities were noted when comparing the aircraft speed on approach against the company's standard operating procedures (SOP) (see Section 1.17.1).

1.11.2 Data from a second flight data recorder

Shortly after the occurrence, although not as a result of it, the operator distributed a revision[12] to the SOPs (see Section 1.17.1.13).

The TSB examined the data from a second FDR, which was installed on a different Jazz DHC-8-102 aircraft and which contained data from approximately 300 flights that occurred after the AOM changes were promulgated.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

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11 A flight data recorder is a device that is installed on an aircraft and records specific aircraft parameters onto a medium designed to be crash-tolerant.

12 *Jazz Dash 8 AOM Volume 2: Aircraft Operating Manual Revision 7*, Subsection 2.7.27, revised on 01 January 2015, but promulgated after the occurrence.

1.14 Fire

Not applicable.

1.15 Survival aspects

Not applicable.

1.16 Tests and research

1.16.1 TSB laboratory reports

The TSB completed the following laboratory reports in support of this investigation:

- LP046/2015—FDR Download and Analysis
- LP089/2015—NVM [Non-volatile Memory] Recovery TAWS

1.17 Organizational and management information

1.17.1 Jazz standard operating procedures

The company's DHC-8-100 series and DHC-8-300 series aircraft SOPs are published in the *Jazz DASH 8 AOM Volume 2: Aircraft Operating Manual*.[13]

Numerous sections of the SOPs pertain to specific phases of flight. With regard to the required speed on approach, guidance for flight crews can be found in several different sections.

1.17.1.1 Vref selection

To determine safe speeds for takeoff and landing given various weights, flap settings, or icing conditions, flight crews use take-off and landing speed (TOL) cards. The TOL cards are a set of small, quickly accessible flip charts that summarize information from the aircraft flight manual.

For the occurrence approach, given the landing weight of just less than 30 000 pounds, flap setting of 15°, and no expected in-flight icing, the applicable TOL card indicates a Vref of 96 knots.

1.17.1.2 Approach speed bug setting

Paragraph 2.7.2(8) of the AOM instructed flight crews to set the approach speed bugs to "Vref +5 knots (plus ½ the wind gust to a maximum of 10 knots)" during approach preparation.[14]

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13 At the time of the occurrence, the manual in effect was Revision 6, revised in March 2014.

14 *Jazz Dash 8 AOM Volume 2: Aircraft Operating Manual Revision 6*, paragraph 2.7.2(8), "Set Approach Speed Bugs," March 2014.

The crew of the occurrence flight determined that an addition for gust was not necessary, and set the approach speed bugs to 101 knots.

1.17.1.3 Target speeds

Subsection 2.7.28 of the AOM indicated that during transition to approach, the gear and flap should be up (clean) and the target speed is 150 knots.[15]

Once the aircraft is established on a non-precision approach, such as the occurrence approach, this subsection indicates that the target speed is 120 knots.

1.17.1.4 Profile speeds

Once the aircraft is on the inbound track of a non-precision approach, such as the one executed on the occurrence flight, Subsection 7.1.5 of the AOM instructed the flight crew to lower the landing gear, set the flaps to 15 degrees, complete the landing checks, and reduce the airspeed to 120 knots.[16]

1.17.1.5 Stabilized approach factors

Subsection 2.7.27 of the AOM indicated that under normal conditions in visual meteorological conditions, the aircraft shall be in a stabilized approach by 500 feet height above aerodrome.[17] The list of stabilized approach components included the following:

> - Stabilized Approach: Stabilized airspeed, stabilized sink rate, and a constant profile. […]
> - Reference Speed: Vref +5 knots […]
> - Final Approach Speed: Normally maintain Vref +5 knots to 500 feet then gradually reduce to achieve Vref at touchdown.[18]

1.17.1.6 Speed deviation tolerance

Subsection 1.1.22 of the AOM indicated that for airspeed deviations greater than +10 knots and −0 knots,[19] the PM is to call "airspeed" and reference the deviation, if required. The PF is to respond "correcting."[20]

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15 Ibid., Subsection 2.7.28, "Target Speeds & Minimum Manoeuvring Speeds," March 2014.

16 Ibid., Subsection 7.1.5, "Non-Precision Approach 2 Engines," March 2014.

17 Ibid., Subsection 2.7.27, "Stabilized Approach Factors," March 2014.

18 Ibid.

19 "−0 knots" with reference to speed tolerance is commonly understood to mean not below.

20 Ibid., Subsection 1.1.22, "SOP Calls Summary," March 2014.

1.17.1.7 *Missed approach procedures*

Subsection 2.9 of the AOM instructed the flight crew to conduct a missed approach if the runway environment is lost to view below minimums.[21]

This subsection also indicated that "failure to achieve or maintain a stabilized condition is the basis for a missed approach."[22]

1.17.1.8 *Flight crew perception of procedures*

At the time of the occurrence, the flight crew's understanding of the appropriate airspeeds for normal operations was as follows:

- 150 knots during descent to 500 feet;
- 120 knots from 500 feet to 200 feet; and
- Bugged speed (Vref + 5 knots) from 200 feet to touchdown, achieved by power reduction as necessary.

1.17.1.9 *Systemic deviance from stable approach*

To determine if the disparities noted on the occurrence flight were an exception to normal operations, the remaining 285 flights recorded on the occurrence aircraft's FDR were examined for similar SOP deviances.

A review of speed at 400 feet on approach found that 84%[23] of recorded flights exceeded the 10-knot allowable tolerance over the required stabilized approach speed (Vref + 5 knots) below 500 feet.

The average exceedance was 17 knots; in other words, the average speed below 500 feet was Vref + 22 knots.

1.17.1.10 *Decelerating approach*

Several other speed averages were determined during the review, including the following:

Table 1. Average speed during descent on approach for all recorded flights on the occurrence flight data recorder

Average speed (knots)	Altitude (feet)
131	1000

21 Ibid., Subsection 2.9, "Missed Approach and Go-Around", March 2014.

22 Ibid.

23 TSB Laboratory Report LP046/2015 determined that on 84% of the recorded flights, the approach speed exceeded the tolerance limit, assuming there was no icing on approach. If maximum speed additions were added to each examined flight to account for icing and wind gusts, only 29% exceeded the limit.

119	500
115	200
113	100

As shown by the decreasing average speeds, the recorded flights were in a constant state of deceleration during approach, including when below 500 feet.

1.17.1.11 Power reduction on approach

On approximately 3% of examined flights, there was significant power reduction toward flight idle below 500 feet, similar to the occurrence flight. On each of these flights, the speed was well above Vref + 5 knots at the time of reduction.

1.17.1.12 Go-arounds

Although the FDR data indicated that the majority of recorded flights were outside of the criteria for a stable approach, none of the flights resulted in a missed approach or go-around.

1.17.1.13 Post-occurrence manual revision

Shortly after the occurrence, although not as a result of it, the operator issued a revised[24] "Stabilized Approach Factors" subsection of the AOM to include the following statements:

- Stabilized airspeed is normally equal to the bugged approach speed
- Deviations of +10 knots to -5 knots are acceptable if the airspeed is trending toward bugged approach speed

The TSB's examination of the data from the second FDR, which recorded flights between 31 March 2015 and 29 May 2015 (shortly after the AOM revisions were promulgated), determined that, in terms of speed exceedance and approach deceleration, the results were similar to those from the occurrence FDR.

1.17.2 Jazz safety management system

Jazz holds a valid air operator certificate and operates aircraft according to CARs Subpart 705. The company has had a Transport Canada–approved safety management system (SMS) since June 2009.

According to the company's SMS manual, *Jazz Corporate Safety and Quality Manual*, aspects of the SMS are delegated to and managed by its independent Safety, Quality and Environment (SQE) department, in order to achieve a coordinated, integrated approach to safety for the entire company.

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24 *Jazz Dash 8 AOM Volume 2: Aircraft Operating Manual Revision 7*, Subsection 2.7.27, revised on 01 January 2015, but promulgated after the occurrence.

The flight crew reported this occurrence as required under the SMS protocol. The company SQE department investigated the event and completed a report detailing the investigation findings, causal factors, and corrective or mitigation plan.

As part of its investigation, the SQE department examined the company's SMS database for similar reports of unstable approaches below 500 feet, but was unable to identify any such events. Its investigation did not examine recorded flight data from other flights to determine if the unstable approach was a systemic issue or an isolated event.

One of the SQE department's findings in the investigation report was that, after the minimum descent altitude,[25] the crew did not maintain a stable approach airspeed.

Under the heading of "Causal Factors," the report stated that procedures regarding approach speeds and AOM guidance language regarding stable approaches needed improvement.

The corrective or mitigation plan detailed in the report did not include any short- or long-term action that would address the identified causal factors.

1.17.3 *Jazz flight data monitoring*

Jazz operates several different aircraft types in its fleet, including de Havilland DHC-8-102s, 300s and 400s, as well as Bombardier CRJ-200s and 705s.

The DHC-8-400s and CRJs are slightly more modern aircraft and are monitored within a flight data monitoring/analysis (FDA)[26] program. The FDA program regularly monitors various parameters of flight and alerts the SQE department to events (such as unstable approaches) or trends that might require further investigation.

Currently, the DHC-8-102s and 300s are not monitored within Jazz's FDA program. When the program began, the future status of these types of aircraft with the operator was uncertain, and, as a result, the investment required to add these types to the FDA program was delayed.

1.17.4 *Operator analysis of flight data from TSB investigation*

Following the TSB's determination that there appeared to be a systemic deviance from stabilized approach SOPs, particularly the recorded airspeeds at 400 feet, the TSB communicated these results to the operator.

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25 Minimum descent altitude is defined as "the altitude above sea level (ASL) specified in the *Canada Air Pilot* (CAP) or the route and approach inventory for a non-precision approach, below which descent shall not be made until the required visual reference to continue the approach to land has been established." (Transport Canada, "Glossary for Pilots and Air Traffic Services Personnel".)

26 FDA (flight data analysis) in this context is synonymous with FDM (flight data monitoring).

The operator responded that it recognized that the occurrence flight was unstable due to the large power reduction and decrease in airspeed from 122 knots to 96 knots below 500 feet.

The company stated that the average Vref + 5 knots exceedance of 17 knots at 400 feet was reflective of the fact that crews were targeting 120 knots—the target speed set out in the AOM target speed subsection.

The company indicated that it was the pilot's responsibility to understand that the target speed of 120 knots, while a good initial target speed as the aircraft undergoes configuration for landing, would be an inappropriate speed to maintain below 500 feet with a briefed bug speed of 96 knots.

The company believes that current industry guidance on stabilized approach criteria allows for a range of speeds to be defined by the operator within its stabilized approach factors program. Therefore, as long as it is not excessive, Jazz considers a speed reduction from an SOP target speed to the minimum manoeuvring speed (Vref + 5 knots) to be stable.

1.18 Additional information

1.18.1 Stabilized approaches

1.18.1.1 Description

In its Advisory Circular AC 120-108, *Continuous Descent Final Approach*, dated 20 January 2011, the Federal Aviation Administration (FAA) of the United States Department of Transportation states, "A stabilized approach is a key feature to a safe approach and landing. […] The stabilized approach concept is characterized by maintaining a stable approach speed, descent rate, vertical flightpath, and configuration to the landing touchdown point".

1.18.1.2 Benefits of a stabilized approach

The safety benefits derived from a stabilized approach have been recognized by many organizations, including the International Civil Aviation Organization, the FAA, the European Aviation Safety Agency, and Transport Canada Civil Aviation.[27] According to the Flight Safety Foundation (FSF),[28] some of the benefits are

- increased overall situational awareness;
- more time and attention for monitoring ATC, weather, and systems;
- more time for monitoring and backup by the PM; and
- defined flight-parameter-deviation limits and minimum stabilization heights to support the decision to land or to go around.

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27 Transport Canada, Civil Aviation Safety Alert (CASA) No. 2015-04, "Stabilized Approach," 06 August 2015.

28 Flight Safety Foundation, "Approach-and-landing Accident Reduction (ALAR) Tool Kit, Briefing Note 7.1 — Stabilized Approach," *Flight Safety Digest* (August–November 2000).

Specific limits on excessive deviation for approach elements, along with a stabilization altitude limit, provide pilots (PF and PM) with a shared reference point, thereby reducing the possibility of ambiguity. In such a context, deviations are detected more quickly and callouts are faster and more accurate.

1.18.1.3 *Industry standard*

Although not specifically required by regulation, most airline operators—including Jazz—have incorporated stabilized approach criteria into their SOPs.

To assist operators in developing these criteria, numerous organizations have established guidelines as to what factors should be considered or defined as part of these criteria. These guidelines are generally very similar and follow the stable concept; however, some differ when it comes to the level of specificity on certain factors, namely speed.

With regard to speed on approach, the following is a list of organizations and their recommendations:

- FSF: Indicated airspeed between Vref and Vref + 20 knots.[29]
- Airbus: Airspeed not lower than Vapp[30] − 5 knots or greater than Vapp + 10 knots.[31]
- Transport Canada (TC): a range of speeds specific to the aircraft type.[32]

Individual airline operators in Canada have adjusted these guidelines as necessary to suit their specific aircraft types and operations. Examination of the stable approach speed requirements of 2 other DHC-8 operators in Canada showed that the SOPs described the limits as Vref to Vref + 10 knots in one case, and Vref to Vref + 15 knots in the other. The limits at Jazz, given the target of Vref + 5 knots, and tolerance of +10 knots or −0 knots, would equate to limits of Vref + 5 knots and Vref + 15 knots; these are consistent with practices recommended by TC and the FSF.

1.18.1.4 *Risk of unstable approach*

The FSF, following the recommendations of its Approach-and-Landing Accident Reduction (ALAR) Task Force, created and distributed an ALAR tool kit, which was intended to reduce the number of approach-and-landing accidents (ALA). Within the tool kit, the FSF stated that the leading cause of ALAs was unstable approaches that continue to landing.

Unstable approaches require constant monitoring of flight parameters such as airspeed, approach angle, and visual references, as well as frequent adjustments to maintain appropriate flight parameters.

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29 Ibid.

30 Vapp refers to the target final approach speed.

31 Airbus, "Flight Operations Briefing Notes, Approach Techniques—Flying Stabilized Approaches, Revision 02," October 2006.

32 Transport Canada, Civil Aviation Safety Alert (CASA) No. 2015-04, "Stabilized Approach," 06 August 2015.

According to the ALAR Task Force, unstable approaches were a causal factor in 66% of ALAs and serious incidents around the world between 1984 and 1997. They were related to improper energy management and, in 36% of cases, they occurred when the aircraft was slow, low, or a combination of both, during the approach.[33] Further research in 2013 indicated that 3% to 4% of all approaches are unstable, and 97% of these are continued to a landing.[34]

The FSF International Advisory Committee recently completed a study regarding stabilized approaches and industry best practices. As a result, the FSF is currently reviewing its recommendations for possible modifications.

Many TSB investigations have highlighted the risk of unstable approaches.

TSB aviation investigation A12Q0161, which examined a similar accident involving a DHC-8-301 that sustained a hard landing and aft fuselage strike in 2012, linked the unstable approach to situational awareness. In that occurrence, the workload associated with completing an unstable approach reduced situational awareness. The PF did not notice the aircraft's energy deficit, nor did the PM anticipate or perceive the action of the PF, who reduced the power 4 seconds from landing. The attention of both pilots was focused outside the aircraft. Neither pilot was able to refocus attention inside the cockpit in time to understand the aircraft configuration and subsequently react to prevent the hard landing.

The TSB identified the need to reduce the incidence of unstable approaches that are continued to a landing in its investigation (A11H0002) into the controlled-flight-into-terrain accident in Resolute Bay, Nunavut. The Board recommended that

> Transport Canada require CARs Subpart 705 operators to monitor and reduce the incidence of unstable approaches that continue to a landing.
>
> **TSB Recommendation A14-01**

1.18.2 Transport Canada safety alert

In response to TSB Recommendation A14-01, TC published a Civil Aviation Safety Alert (CASA) entitled "Using SMS to Address Hazards and Risks Associated with Unstable Approaches" (CASA No. 2014-03) in June 2014.

The purpose of the CASA was, in part,

> To request Canadian air operators operating under subpart 705 of the Canadian Aviation Regulations (CARs) that they use—on a voluntary basis—

33 Flight Safety Foundation, "Approach-and-landing Accident Reduction (ALAR) Tool Kit, Briefing Note 4.2 – Energy Management," *Flight Safety Digest* (August–November 2000).

34 J. M. Smith, D. W. Jamieson and W. F. Curtis, "Failure to Mitigate," *AeroSafety World*, Flight Safety Foundation, Volume 8, Issue 1 (February 2013).

> their existing Safety Management System (SMS) to address and mitigate hazards and risks associated with unstable approaches[.][35]

In the CASA, TC requests that this hazard be assessed and mitigated through appropriate use of SMS components, including, but not limited to, the following:

- safety oversight (reactive and proactive processes);
- training and awareness (promotions); and
- voluntary use of Flight Data Monitoring[36] (in order to gain a greater understanding of unstable approaches and the causes).

> This may be determined by performing a proactive assessment of unstable approach hazards (including situations where this is more likely to occur), a review of SMS database to verify the rate of occurrence and to ensure this is being reported and finally, follow up with the pilot community to verify it is being reported and monitored through the SMS in order to verify a decrease in incidents and increased awareness of the hazard and attendant risks.
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> Alternatively, air operators who indicate that they do not have a problem with unstable approaches in their operation will be asked to demonstrate how they have reached this conclusion. Air operators with an established flight data monitoring program (FDM) are encouraged to use this program to gather and analyze this data.[37]

TC has identified a follow-up initiative designed to measure the effectiveness of CASA No. 2014-03. Specifically, the purpose of its Internal Process Bulletin 2016-01 is to examine an operator's assessment of unstable approaches using its SMS and, where applicable, review established mitigations and the extent, type, and frequency of interventions related to unstable approaches.

The TSB looks forward to the opportunity to review TC's analysis in order to better understand what measures airlines have implemented and assess whether they are effective in addressing the underlying safety deficiency associated with Recommendation A14-01.

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35 Transport Canada, Civil Aviation Safety Alert (CASA) No. 2014-03, "Using SMS to Address Hazards and Risks Associated with Unstable Approaches," 27 June 2014.

36 Flight data monitoring is a program whereby digital flight data generated during line operations is collected and analyzed to provide greater insight into the total flight operations environment. (Transport Canada, Commercial and Business Aviation Advisory Circular No. 0193, "Flight Data Monitoring (FDM) Programs," 01 November 2001).

37 Transport Canada, Civil Aviation Safety Alert (CASA) No. 2014-03, "Using SMS to Address Hazards and Risks Associated with Unstable Approaches," 27 June 2014.

1.18.3 Decision making

1.18.3.1 Plan continuation bias

In a National Aeronautics and Space Administration (NASA) and Ames Research Center review of 37 accidents investigated by the United States National Transportation Safety Board, it was determined that almost 75% of the tactical decision errors involved in the 37 accidents illustrated "a common theme: many were errors in which the crew decided to *continue with the original plan of action in the face of cues that suggested changing the course of action*" (emphasis in original).[38]

This theme is often referred to as "plan continuation bias" or "plan continuation error."[39] Aviation references define this theme similarly as "the unconscious cognitive bias to continue with the original plan in spite of changing conditions"[40] or "a deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan."[41]

Plan continuation bias has been linked to situational awareness.[42, 43] For example, pilots may not detect an environmental change (that is, the pilots experience reduced situational awareness) that decreases flight safety, and this may lead to the decision to continue an approach or landing in unsafe conditions.

Plan continuation bias is also related to workload. Pilots are more likely to experience plan continuation bias in higher workload conditions.[44] Aviation references also note this relationship and that it is more likely to occur

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38 J. Orasanu, L. Martin, and J. Davison, "Errors in Aviation Decision Making: Bad Decisions or Bad Luck?" NASA–Ames Research Center paper presented at the Fourth Conference on Naturalistic Decision Making. Warrington, Virginia, May 29–31, 1998.

39 J. Orasanu, L. Martin, and J. Davison, "Cognitive and Contextual Factors in Aviation Accidents: Decision Errors," *Linking Expertise and Naturalistic Decision Making*, ed. E. Salas and G. A. Klein (Mahwah, New Jersey: Lawrence Erlbaum Associates, Inc., 2001), 209-225.

40 See for example the definition in EUROCONTROL SKYbrary, "Continuation Bias" available at: http://www.skybrary.aero/index.php/Continuation_Bias (last accessed 07 February 2017).

41 B. Berman and R. K. Dismukes, "Pressing the approach," *Aviation Safety World*, Flight Safety Foundation, Volume 1, Issue 6 (December 2006).

42 "Situational awareness" is a term adopted by the International Civil Aviation Organization.

43 See the following for examples:
(A) J. Goh and D. A. Wiegmann, "Visual flight rules flight into instrument meteorological conditions: An empirical investigation of the possible causes," *The International Journal of Aviation Psychology*, Volume 11, Issue 4 (2001).
(B) J. Orasanu, L. Martin, and J. Davison, "Cognitive and Contextual Factors in Aviation Accidents: Decision Errors," *Linking Expertise and Naturalistic Decision Making*, ed. E. Salas and G. A. Klein (Mahwah: Lawrence Erlbaum Associates, Inc., 2001), 209-225.

44 E. Muthard and C. Wickens, "Factors that mediate flight plan monitoring and errors in plan revision: Planning under automated and high workload conditions." Paper presented at the 12th International Symposium on Aviation Psychology, Dayton, Ohio (2003).

> as the culmination of a task nears, for example during the flying of an approach to land or the maintenance of the planned separation between aircraft sequenced for approach to a particular runway.[45]

1.18.3.2 Confirmation bias

Confirmation bias is a well-researched and validated decision-making phenomenon first documented in 1960.[46] In an aviation context, the bias can predispose pilots to seek cues confirming the belief that any decision to continue an approach is the correct one. In other words, as pilots complete an approach, they are more likely to seek, and therefore find, information that would lead them to believe that continuing the approach is a safe decision.

Confirmation bias may play a role in plan continuation errors. Under this bias, pilots are less likely to detect changes that refute the belief that continuing with the current plan is safe.

1.18.4 TSB Watchlist

The TSB Watchlist is a list of key safety issues in Canada's transportation system that the TSB publishes to focus the attention of industry and regulators on the problems that need addressing today.

1.18.4.1 Unstable approaches are an issue on the 2016 Watchlist

Every year, there are millions of successful landings on Canadian runways. However, unstable approaches significantly increase the risk of accidents during the landing phase of a flight—accidents that can result in aircraft damage, injuries, and even fatalities.

International research indicates that among commercial operators, 3.5% to 4% of approaches are unstable.[47] Of these, 97% are continued to a landing, with only 3% resulting in a go-around, despite airlines' stable-approach policies.

If operators' stable-approach policies are not complied with, pilots will continue unstable approaches to a landing, increasing the risk of approach-and-landing accidents.

The tools being used by some airlines to improve flight crew compliance include flight data monitoring, flight operations quality assurance programs, explicit standard operating procedures, and non-punitive go-around policies. However, major airlines need to expand the use of these tools, evaluate them to confirm that they are effective at reducing the number of unstable approaches continued to a landing, and integrate them fully into their SMSs.

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45 EUROCONTROL SKYbrary, "Continuation Bias," available at: http://www.skybrary.aero/index.php/Continuation_Bias (last accessed on 02 February 2017).

46 P. C. Wason, "On the failure to eliminate hypotheses in a conceptual task," *Quarterly Journal of Experimental Psychology*, Volume 12, Issue 3 (1960).

47 J. M. Smith, D. W. Jamieson and W. F. Curtis, "Failure to Mitigate," *AeroSafety World*, Flight Safety Foundation, Volume 8, Issue 1 (February 2013).

1.19 Useful or effective investigation techniques

Not applicable.

2.0 Analysis

2.1 General

Records indicate that the flight crew were certified and qualified for the flight in accordance with existing regulations, and there were no indications that fatigue was a factor. The aircraft was serviceable during the occurrence approach.

Although there were post-occurrence reports that an individual precision approach path indicator (PAPI) light may have been physically obscured, there was no indication that this was an issue during the occurrence approach, and the airport lighting and visual aids to navigation were likely working adequately during the approach.

Therefore, this analysis will examine the underlying factors behind 4 main issues:

- why the approach was not stable;
- why the unstable condition went unrecognized;
- why the aircraft deviated from the intended vertical path; and
- why a go-around was not initiated following loss of visual cues.

2.2 Approach

2.2.1 Weather

The weather system moved in from the west very quickly, and rapidly reduced runway visibility, beginning at the departure end of Runway 30. Air traffic control (ATC) informed the crew several times of the decreasing visibilities sensed by the transmissometer at the end of the runway.

The crew had no way to ascertain the speed at which the weather system was advancing across the runway and, because the runway was in sight when they approached the minimum descent altitude (MDA), they chose to continue the approach.

2.2.2 Speed on approach

The crew followed what they understood to be the correct speeds for the approach.

Both crew members set the approach speed bugs at 101 knots prior to commencing the approach, as per the standard operating procedures (SOP). This speed was understood to be the speed to which the aircraft should reduce, from 120 knots, after descending through 500 feet. It was the pilot flying's (PF) regular routine to achieve this deceleration with power reductions at 200 feet. However, on the occurrence approach, the PF reduced power to idle to reduce the approach speed from 122 knots toward 101 knots at 200 feet above ground level. This steepened the aircraft's vertical path.

2.2.3 Change to vertical path

The angle of the aircraft's established vertical path before the power reduction at 200 feet would have resulted in the aircraft arriving near the normal touchdown zone of the runway, albeit at an airspeed in excess of Vref.

When the power was reduced toward flight idle at 200 feet, the aircraft began to decelerate rapidly. The aircraft's nose-up pitch was gradually increased and vertical speed was relatively stable; however, the vertical path steepened due to the decreasing airspeed and resultant ground speed reduction.

Below 200 feet, the pilots would normally have visual contact with the runway environment and associated runway approach lighting. With these visual cues available, the resulting steepening of the vertical profile would normally be detected and corrected by further increased nose-up pitch or increased power where necessary.

On the occurrence approach, visual contact with the runway was lost somewhere below 200 feet. With a runway visual range (RVR) visibility of 1200 feet, the PAPI lights—normally the best source of visual vertical path guidance—would not be visible until the aircraft was almost over the runway threshold.

The rapidly decreasing visibility resulted in the airport environment and the PAPI lights becoming obscured; as a result, the steepened vertical profile went unnoticed and uncorrected.

2.2.4 Continuation following loss of visual cues

2.2.4.1 Training

Part of the flight crew training at Jazz Aviation LP (Jazz), which both crew members had completed, involved a simulator exercise that included initiating a go-around following loss of visual cues at approximately 100 feet on approach. However, neither could recall ever having actually performed a real-life go-around under such conditions.

2.2.4.2 Confirmation bias

Confirmation bias can predispose pilots to seek cues confirming the belief that any decision to continue an approach is the correct one. In other words, pilots on approach are more likely to seek, and therefore find, information that would lead them to believe that continuing an approach is a safe decision.

In this occurrence, the speeds flown on approach were relatively close to the flight crew's understanding of what was required for a stabilized approach. This may have led to confirmation bias, in that the crew may not have acknowledged the decelerating speed or loss of visibility, but rather chose to focus on the perception of stability. Their history of successfully continuing approaches once already below the MDA reinforced the notion that the plan to continue was an appropriate option.

2.2.4.3 *Plan continuation bias*

Plan continuation bias can be described as a "deep-rooted tendency of individuals to continue their original plan of action even when changing circumstances require a new plan."[48]

A number of factors can increase the likelihood that a pilot will experience plan continuation bias and continue an approach or landing in unsafe conditions. These include

- a culmination of tasks;
- questionable weather;
- decreased situational awareness;
- higher workload;
- unstable approaches; and
- confirmation bias.

With regard to the occurrence flight, at the culmination of the approach, the aircraft encountered rapidly changing weather, and visibility was lost.

The crew had no cues to ascertain the vertical approach path after leaving 200 feet. Once visibility had deteriorated in the blowing snow, the crew perceived that the aircraft was very close to the ground and, therefore, very near to the runway. This perception is indicative of reduced situational awareness.

The crew were experiencing a higher workload at this moment because the approach speed was unstable, and power and pitch needed to be altered to achieve the planned speed reduction. Focus was being divided between looking outside at the weather and looking inside to monitor approach parameters.

The flight crew perceived the aircraft to be in a stable condition, and had never before needed to carry out a go-around due to weather once the aircraft was already below the MDA. The aforementioned confirmation bias likely led the crew to focus on these positive factors suggesting that the approach was safe while diverting their attention away from the factors that would suggest otherwise.

The *Jazz DASH 8 AOM Volume 2: Aircraft Operating Manual* (AOM) instructed flight crews to conduct a missed approach if the runway environment was lost to view below minimums. However, the combination of a higher workload resulting from the unstable approach, decreased situational awareness in deteriorating weather, and confirmation bias at the culmination of the approach likely led to plan continuation bias. Although the loss of visual reference required a go-around, the crew continued the approach to land as a result of this plan continuation bias.

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48 B. Berman and R. K. Dismukes, "Pressing the approach," *Aviation Safety World*, Flight Safety Foundation, Volume 1, Issue 6 (December 2006).

2.2.5 Ground contact

As the approach continued toward landing following the loss of visibility, the crew likely expected the terrain awareness and warning system (TAWS) to issue an alert with respect to the aircraft's height as the aircraft came in close proximity to the ground.

However, the TAWS did not alert the crew to the aircraft's proximity to the ground once the aircraft was below 50 feet, possibly due to the rapid rate of closure. This lack of warning contributed to the crew not being aware of the aircraft's height above ground.

Due to the uncorrected steepened vertical profile, loss of visual reference, and lack of normal terrain warning, the aircraft contacted the surface approximately 450 feet prior to the runway threshold.

2.3 Operator

2.3.1 Stabilized approaches

Stabilized approaches are not a regulatory requirement. However, given the accident history and numerous studies and reports, most operators, including Jazz, have adopted a stable approach philosophy and incorporated stable approach criteria into their SOPs.

Operators develop their own stable approach criteria, and often do so with the assistance of published guidance from organizations such as the Flight Safety Foundation or other industry partners.

The exact details of the adopted stabilization criteria often differ from one operator to the next, and speed tolerance can vary between 0 and 20 knots. However, whichever target speed is chosen, the stabilized approach concept is meant to be characterized by the maintaining of a stable approach speed. That is, the objective is not to accelerate or decelerate from one end of the tolerance limit to the other during final approach.

Examination of flight data from over 500 flights recorded on 2 separate Jazz flight data recorders (FDR) showed that company aircraft routinely fly decelerating approaches, including when below the minimum stabilization height of 500 feet.

The requirement to decelerate contributes to additional crew workload and monitoring to adjust or correct the deceleration, which distracts the crew from potentially higher-priority tasks, such as monitoring the flight path, weather, or other flight parameter exceedances.

If approaches that require excessive deceleration below established stabilization heights are routinely flown, then there is a continued risk of an approach or landing accident.

2.3.2 Standard operating procedures

The AOM in effect at the time of the accident included several sections that described the required speed on approach. It also stated that "failure to achieve or maintain a stabilized condition is the basis for a missed approach."[49]

Before the approach, crews are instructed to set the approach speed bug to Vref + 5 knots. At the aircraft's lowest weight, Vref would be 87 knots, so this bug could be set as low as 92 knots.

The "Stabilized Approach Factors" subsection echoed this bugged number, stating that final approach speed should be Vref + 5 knots and should be reduced to achieve Vref by the runway threshold.

The "Profiles" and "Target Speeds" subsections of the AOM called for a speed of 120 knots, once the aircraft is established on approach.

Given the disparity in the guidance at the time of the occurrence of as much as 28 knots, it would be difficult for a crew member to notice a deviation that exceeded the specified tolerance limit of +10 to −0 knots. Depending on the speed the PF was targeting, the perceived acceptable speed range could be between 87 and 130 knots.

Jazz included new training in the 2014–2015 simulator training cycle to train pilots to recognize an unstable approach and initiate a go-around; however, the occurrence crew members had not yet completed this training at the time of the occurrence.

If guidance provided to flight crews allows for large tolerance windows, and crews are not trained to recognize an unstable condition, then there is a continued risk that flights that are unstable will be continued to a landing.

2.3.3 Examination of flight data

2.3.3.1 Stabilized criteria exceedance

Examination of the data from the occurrence aircraft's FDR showed that, on approach at 500 feet above ground level, the aircraft was 21 knots above the required stabilized airspeed of 101 knots.

Further examination of the data from the remaining flights recorded on the occurrence FDR, and additional data from a second FDR, showed that the average deviation for all flights at an altitude 100 feet below the minimum stabilization altitude was 17 knots.

When this information was relayed to the operator, the operator stated that it believed this deviation reflected the fact that the crews were targeting 120 knots, rather than

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49 *Jazz Dash 8 AOM Volume 2: Aircraft Operating Manual Revision 6*, Subsection 2.9, "Missed Approach and Go-Around," March 2014.

Vref + 5 knots, and that it is the flight crew's responsibility to recognize that 120 knots is an inappropriate speed below 500 feet if the bugged speed is 96 knots.

The average recorded deviation of 17 knots from bugged speed at 400 feet would suggest that, in fact, crews are not recognizing the unsuitability of this deviation. Because the SOP guidance regarding the target speed varies between 120 knots and Vref + 5 knots, this lack of recognition is likely due to the ambiguity in the guidance.

On the occurrence flight, due to ambiguity in the guidance and uncertainty as to the required speeds during the approach, the crew did not recognize that the approach was unstable, and continued.

2.3.3.2 Decelerating approach

Examination of the speed of all recorded flights at various altitudes below 1000 feet during final approach showed that, in general, there was a steady deceleration on approach, even once below the 500-foot minimum stabilization height.

The operator's position is that current industry guidance on stabilized approach criteria allows for a range of speeds to be defined by the operator within its stabilized approach factors program. Therefore, a reduction of speed from the 120-knot target to the minimum manoeuvring speed (Vref + 5 knots) would be considered stable by Jazz, as long as the reduction is not excessive.

The operator does not define, either in its response to the TSB or within the company manuals, what would be considered an excessive reduction; however, any planned or intentional deceleration would diverge from the stable approach concept, which requires a stable airspeed.

The company SOPs require an approach speed of Vref + 5 knots; however, this is being interpreted by flight crews as a target to which they should decelerate, from 120 knots, once the aircraft is below 500 feet. As a result, the majority of examined approaches, including the occurrence approach, were unstable, due to this deceleration.

It is possible that flight crews have adopted this style of decelerating approach, in general, in an effort to accommodate frequent ATC requests for higher speeds on approach. However, there was no evidence to suggest that the occurrence crew were maintaining higher speeds during this particular approach as an accommodation to ATC.

2.3.4 Safety management system

2.3.4.1 Using safety management systems to address unstable approach risk

In response to TSB Recommendation A14-01, Transport Canada published a Civil Aviation Safety Alert (CASA) entitled "Using SMS to Address Hazards and Risks Associated with Unstable Approaches" in June 2014.

In the absence of flight data monitoring (FDM), the CASA recommends that operators complete a review of their safety management system (SMS) database to verify the rate of occurrence of unstable approaches in order to perform a proactive assessment of the hazard.

The flight crew reported the occurrence as required under the SMS protocol. The company Safety, Quality and Environment (SQE) department investigated the event and completed a report detailing its investigation findings, causal factors, and corrective or mitigation plan.

The SQE investigation report identified that the crew did not maintain a stable approach once below the MDA, and that stable approach language in the AOM needed improvement.

As part of its investigation, the SQE department examined the company's SMS database for similar reports of unstable approaches below 500 feet, but was unable to identify any such events. The SQE investigation did not examine recorded flight data from other flights to determine if the unstable approach was a systemic issue or an isolated event. However, the TSB's examination of FDR data showed that, by the operator's definition, more than 84% of the recorded flights were unstable below 500 feet.

Given the ambiguity in the guidance with regard to speed targets, it is likely that the flight crews of the unstable flights did not recognize the unstable condition. If the unstable condition is not recognized, it will, understandably, not be reported through the operator's SMS.

Therefore, if crews do not report unstable approaches and operators do not conduct FDM but rely only on SMS reports to determine the frequency of unstable approaches, there is a risk that these issues will persist and contribute to an accident.

3.0 Findings

3.1 Findings as to causes and contributing factors

1. The company standard operating procedures require an approach speed of Vref + 5 knots; however, this is being interpreted by flight crews as a target to which they should decelerate, from 120 knots, once the aircraft is below 500 feet. As a result, the majority of examined approaches, including the occurrence approach, were unstable, due to this deceleration.

2. Due to ambiguity in the guidance and uncertainty as to the required speeds during the approach, the crew did not recognize that the approach was unstable, and continued.

3. On the approach, the pilot flying reduced power to idle to reduce the approach speed from 122 knots toward 101 knots at 200 feet above ground level. This steepened the aircraft's vertical path.

4. The rapidly decreasing visibility resulted in the airport environment and the precision approach path indicator lights becoming obscured; as a result, the steepened vertical profile went unnoticed and uncorrected.

5. Although the loss of visual reference required a go-around, the crew continued the approach to land as a result of plan continuation bias.

6. The terrain awareness and warning system did not alert the crew to the aircraft's proximity to the ground once the aircraft was below 50 feet, possibly due to the rapid rate of closure. This lack of warning contributed to the crew not being aware of the aircraft's height above ground.

7. Due to the uncorrected steepened vertical profile, loss of visual reference, and lack of normal terrain warning, the aircraft contacted the surface approximately 450 feet prior to the runway threshold.

3.2 Findings as to risk

1. If guidance provided to flight crews allows for large tolerance windows, and crews are not trained to recognize an unstable condition, then there is a continued risk that flights that are unstable will be continued to a landing.

2. If approaches that require excessive deceleration below established stabilization heights are routinely flown, then there is a continued risk of an approach or landing accident.

3. If crews do not report unstable approaches and operators do not conduct flight data monitoring but rely only on safety management system reports to determine the

frequency of unstable approaches, there is a risk that these issues will persist and contribute to an accident.

4.0 Safety action

4.1 Safety action taken

Jazz Aviation LP (Jazz) has undertaken the following safety actions as a direct result of the occurrence:

- The *Jazz DASH 8 AOM Volume 2: Aircraft Operating Manual* has been amended 3 times since the occurrence and is now on Revision 9. The latest revision has introduced significant changes to the "Stabilized Approach Factors" subsection, including the following items directly related to speed on approach:

  By 1000′ [feet] AFE [above field elevation]

  - Airspeed is trending towards the Target Speed of 120 KIAS [knots indicated air speed] or the bugged approach speed, whichever is higher […]

  By 500′ [feet] AFE

  - Stabilized airspeed shall be at the bugged approach speed. Deviations of +10 knots to -5 knots are acceptable if the airspeed is trending toward bugged approach speed

- Jazz provided the occurrence flight crew with additional training, which included stabilized approaches, missed approaches, poor visibility, and low energy go-arounds.
- Simulator scenarios were added to the training syllabus to reflect the speeds and weights of the occurrence flight.
- Several Flight Safety Briefs, All Pilot Memos, and *Focus on Safety* magazine articles were distributed; these focused on stable approach issues and procedural non-compliance.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 04 January 2017. It was officially released on 09 March 2017.

Visit the Transportation Safety Board's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.