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

AVIATION INVESTIGATION REPORT A14F0065

Unstable approach and hard landing

Air Canada Rouge LP
Airbus A319, C-FZUG
Sangster International Airport
Montego Bay, Jamaica
10 May 2014

Canada

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Summary

The Air Canada Rouge LP, Airbus A319 (registration C-FZUG, serial number 697), operating as flight AC1804, departed Toronto Lester B. Pearson International Airport, Toronto, Ontario, under instrument flight rules for Montego Bay, Jamaica, with 131 passengers and 6 crew members on board. The flight crew was cleared for a non-precision approach to Runway 07 in visual meteorological conditions. The approach became unstable and, at 1429 Eastern Daylight Time, the aircraft touched down hard, exceeding the design criteria of the landing gear. There was no structural damage to the aircraft, and there were no injuries.

Le présent rapport est également disponible en français.

Table of contents

1.0 Factual information

1.1 History of the flight

At 1034,[2] the Air Canada Rouge LP, Airbus A319 (registration C-FZUG, serial number 697), operating as flight AC1804, departed Toronto Lester B. Pearson International Airport (CYYZ), Toronto, Ontario. The flight was the first crew cycle for the 2 pilots. The captain was seated in the left seat and was the pilot flying (PF).[3] The first officer was seated in the right seat and was the pilot monitoring (PM). The aircraft climbed to flight level (FL) 370[4] for the cruise portion of the flight.

At 1359, before descent and approximately 30 minutes before touchdown, the PF performed an approach briefing for the instrument landing system (ILS) approach to Runway 07 at Sangster International Airport (MKJS), Montego Bay, Jamaica. The approach briefing did not include the aircraft go-around procedure or the specific published missed-approach procedure, contrary to Air Canada Rouge policy.

At 1403, the aircraft began its initial descent from FL 370.

The International Civil Aviation Organization (ICAO) Convention on International Civil Aviation, Annex 13,1 requires States conducting accident investigations to protect cockpit voice recordings. Canada complies with this requirement by making cockpit voice recordings privileged under the Canadian Transportation Accident Investigation and Safety Board Act. While the Transportation Safety Board of Canada (TSB) may make use of any on-board recording in the interests of transportation safety, it is not permitted to knowingly communicate any portion of an on-board recording that is unrelated to the causes or contributing factors of an accident or to the identification of safety deficiencies.

Protections for cockpit voice recorder (CVR) material help ensure that this essential material is available for the benefit of safety investigations. The TSB has always met its obligations in this area and has restricted the use of CVR data in its reports. Unless the CVR material is required to both support a finding and identify a substantive safety deficiency, it is not included in the TSB's report.

In this report, the TSB has made extensive use of the cockpit voice recording. In each instance, the material has been carefully examined to ensure that the extracts used are related to the causes or contributing factors of this accident or to the identification of safety deficiencies.

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1 International Civil Aviation Organization (ICAO), Annex 13 to the Convention on International Civil Aviation, Aircraft Accident and Incident Investigation, 10th edition (2010), Amendment 14 (5.12)

2 All times are Eastern Daylight Time (Coordinated Universal Time minus 4 hours).

3 See Appendix D - Glossary for a list of abbreviations and acronyms used in this report.

4 37 000 feet pressure altitude.

At 1405, the flight crew held a non-operational conversation, lasting nearly 3 minutes, in contravention of Air Canada Rouge policies regarding operational conversation during critical phases of flight, including flight from top of descent on arrival.

At 1415, approach air traffic control (ATC) at MKJS asked which specific approach the flight crew preferred, offering the area navigation (RNAV) for Runway 07 or the VOR/DME[5] for Runway 07. At this point, the flight crew became aware of a published Notice to Airmen (NOTAM)[6] specifying that the ILS for Runway 07 was not available. The NOTAM had been included in the company flight release documents before departure but had not been noticed by the flight crew. The crew decided to perform the VOR/DME Runway 07 approach.

At 1417 (12 minutes before landing), the PF re-briefed the PM for the VOR/DME approach to Runway 07. As with the initial approach briefing for the ILS approach to Runway 07, the PF did not brief the aircraft go-around and published missed-approach procedures for the VOR/DME approach to Runway 07. The PF advised that a managed approach[7] would be conducted.

During the re-briefing, the PF indicated that the final approach fix (FAF) crossing altitude was 2000 feet above sea level (asl),[8] with a flight path angle (FPA) of 3.2 degrees.

At 1421:20, the flight crew held a non-operational conversation that ended at 1422:04 (approximately 8 minutes before touchdown), while the aircraft was descending though 10 000 feet.

At 1423:56 (6 minutes before landing), ATC queried whether the flight crew was able to proceed directly to LENAR[9] at that time. The flight crew advised ATC that they were able to do so, and the aircraft was then cleared to LENAR. At this point, the aircraft was being flown using the autopilot and autothrust systems.

At 1424:46, before turning onto the final approach track, the PF selected a target speed of 190 knots on the flight control unit (FCU); the autothrust decreased the thrust and, as a result, the aircraft began to decelerate from 250 knots. The aircraft was level at 3000 feet.

5 VOR/DME is a very-high-frequency omnidirectional range with associated distance measuring equipment.

6 A Notice to Airmen (NOTAM) is a notice filed with an aviation authority to alert aircraft pilots of potential hazards along a flight route or at a location that could affect the safety of the flight.

7 In a managed approach, "the aircraft is guided along the FMS [flight management system] lateral and vertical Flight Plan and speed profile. These modes and targets are armed or engaged by pressing the FCU [flight control unit] knobs." Air Canada Rouge, *Aircraft Operating Manual A319* (AOM), Volume 1 (10 May 2013), Standard Operating Procedures, section 1.04.00, p. 4.

8 All altitudes are above sea level (asl), unless otherwise specified.

9 LENAR is the name of the initial fix for the very high frequency (VHF) omnidirectional range with associated distance measuring equipment (VOR/DME) Runway 07 approach, located 10.8 nautical miles from the threshold of Runway 07.

At 1425:03, the PF requested flaps 1, which is the first configuration change in the approach sequence.

From 1425:28 to 1426:02, the PM was engaged in dialogue with ATC. During this time, the aircraft turned onto its final approach track.

At 1425:44, the final approach track was intercepted from the left (north), at a distance of approximately 9.6 nautical miles (nm) from the threshold (inside of LENAR) (Figure 1). The aircraft was at an altitude of 3000 feet, with flaps 1 selected. According to Air Canada Rouge standard operating procedures (SOP), at this point (4 nm before the FAF), the aircraft should be configured with flaps 2. The autopilot was engaged and the autothrust was on. The airspeed was approximately 200 knots, and the aircraft was slightly above the 2.95-degree precision approach path indicator (PAPI), but below the 3.2° FPA. The aircraft began its final approach descent. Shortly afterward, the flight mode annunciator (FMA) lateral and vertical modes changed to NAV and FINAL DES[10] respectively, indicating that the aircraft was being managed by the flight management and guidance system (FMGS). The selected airspeed was still 190 knots. In these modes, the aircraft will fly the required lateral and vertical flight path, while the autothrust will vary the thrust to maintain the selected speed.

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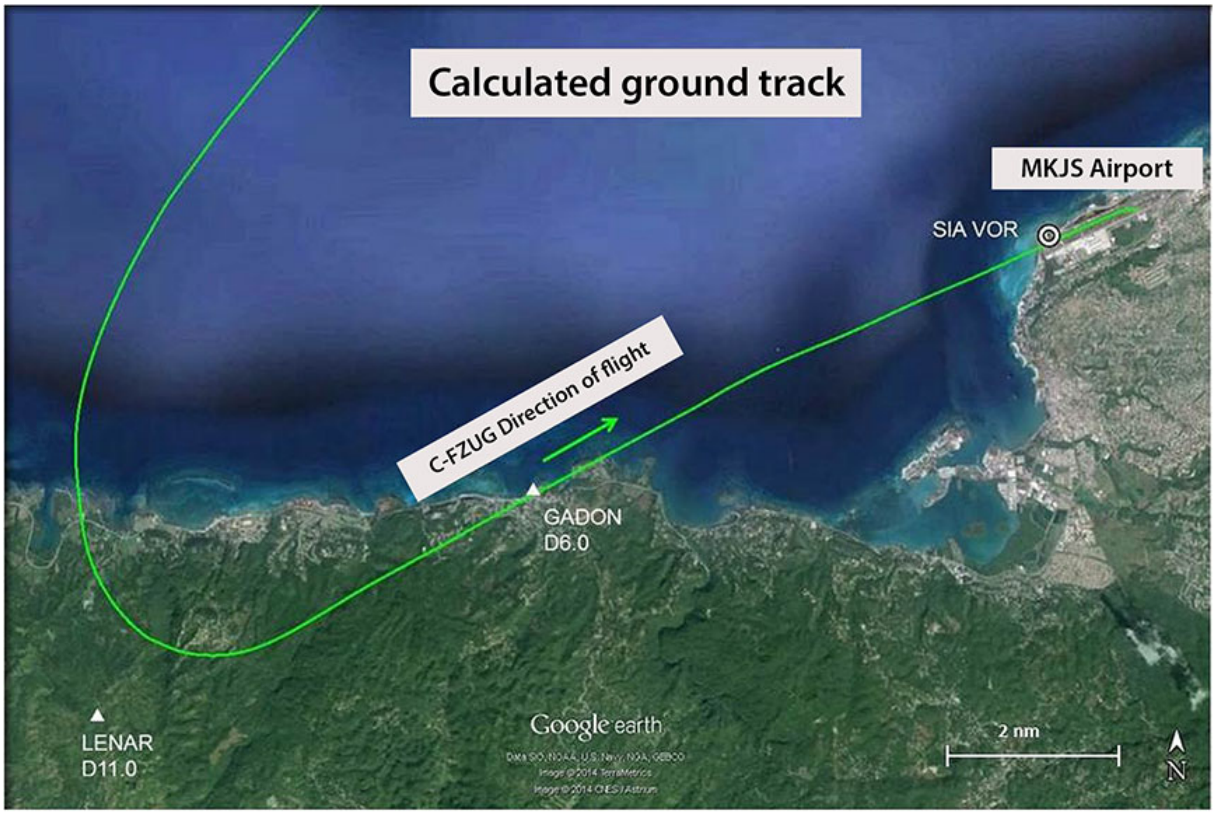
10 The FINAL DES or FINAL annunciation appears on the FMA when the APPR button is pushed while proceeding in NAV. When both the vertical FINAL and lateral APP NAV are captured, FINAL APP is displayed.

Figure 1. Aircraft ground track with approach fixes (Source: Google Earth, with TSB annotations)



At 1426:00, 9.2 nm from the runway, the airspeed slowed to 195 knots. The PF selected a target speed of 180 knots to slow the aircraft down, and the autothrust system reduced the engine thrust to idle. The aircraft was at an altitude of 2950 feet.

At about 1426:08 (8.7 nm from the runway), the PF requested landing gear down to expedite the descent. This request was outside of the normal aircraft configuration sequence in Air Canada Rouge SOPs. The normal sequence is to select flaps 2 before extending the landing gear. However, the SOPs permit flight crew to lower the landing gear at any time during the approach, to aid in the descent.

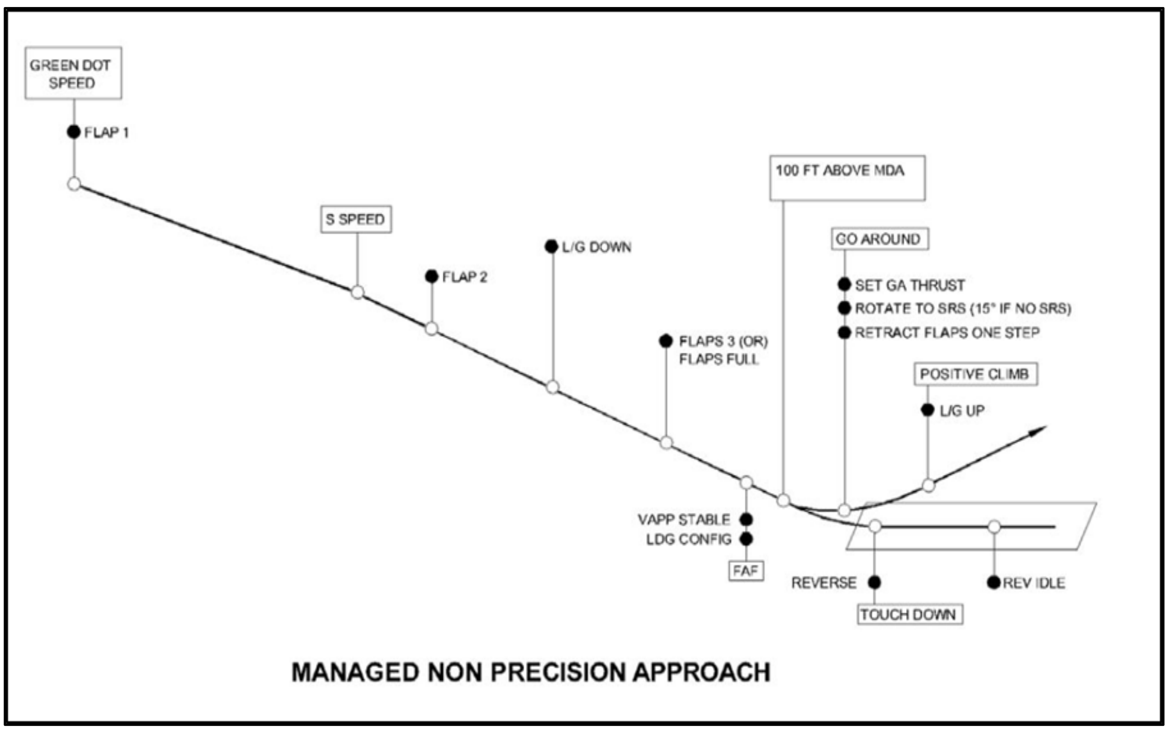
At 1426:25, the airspeed was 188 knots. Using the FCU, the flight crew changed the selected target speed from 180 knots to 190 knots, then to 200 knots. Because of this selection, the autothrust momentarily increased the engine thrust, resulting in an increase in airspeed. The descent rate also increased, reaching 2000 feet per minute (fpm).

At 1426:28, the landing gear was down and locked. The aircraft was 7.7 nm from the runway and 1.7 nm from the FAF, with flaps 1 selected. At this point, according to Air Canada Rouge SOPs, the aircraft should have already been configured with flaps 3 selected.

At 1426:37, the aircraft was 1.6 nm from the FAF. The flight crew changed the target speed from their previous selection of 200 knots to a managed target speed[11] of 134 knots, equivalent to the final approach speed (V_{APP}).[12] At this point, the aircraft's airspeed was 198 knots, and its altitude was decreasing through 2440 feet. As a result of the change in target speed, the aircraft began to decelerate.

At 1427:02, the aircraft crossed the FAF at the appropriate height (2000 feet) with an airspeed of 188 knots (V_{APP} plus 54 knots). At that time, the landing gear was down, with flaps 1 selected. According to Air Canada Rouge SOPs for a non-precision managed approach, at this point the aircraft should have been stable at V_{APP}, with landing gear down and flaps 3 selected (Figure 2).

Figure 2. Air Canada Rouge standard operating procedures for a managed non-precision approach (Source: Air Canada Rouge)



During the FAF crossing, using the vertical speed / flight path angle (VS/FPA) knob on the FCU, the PF selected 3.2° FPA, which is the appropriate FPA from the FAF. The FMA lateral and vertical modes changed to track mode (TRK) and to FPA, respectively. The flight crew did not perform the FAF-passage verbal calls required by the SOPs or their respective actions, which include setting the appropriate missed-approach altitude in the FCU.

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11 The managed target speed is computed by the flight management guidance computer.

12 V_{APP} is calculated by the flight management guidance computer.

At 1427:13, the PF disengaged the autopilot as the aircraft descended through 1780 feet, at a distance of approximately 5.2 nm from the threshold; airspeed was 186 knots. The remainder of the approach was flown manually by the PF, with the autopilot off.

At 1427:16, while the aircraft was descending through 1690 feet, 5 nm from the runway, with an airspeed of 187 knots, the PF requested flaps 3.[13] The PM momentarily selected flaps 3, from flaps 1. The airspeed was 2 knots faster than the maximum flap selection speed for flaps 3, and the PM quickly retracted the flap lever to flaps 2. Contrary to Air Canada Rouge SOPs, the PM did not verbalize that the speed was correct for the selected flap setting, nor did he communicate the changes in flap position to the PF. During these flap selections, there was a radio call from ATC, clearing the aircraft to land.

Although data from the cockpit voice recorder (CVR) indicated that the PF had requested flaps 3, the investigation determined that the PF believed that he had requested flaps 2.

At 1427:22, the flight crew pulled the altitude selector (ALT/SEL) on the FCU. However, the FCU-selected altitude was set at 2000 feet. As a result, since the aircraft was below that altitude, the vertical mode changed from FPA to open climb (OP CLB) mode, and the autothrust changed to climb thrust (THR CLB) mode. The autopilot was off, so the aircraft did not climb, as requested by the automation. However, the autothrust increased the engine thrust from 34% to 87%, which resulted in an increase in airspeed.

At 1427:25, approximately 4.5 nm from the runway, with an airspeed of 185 knots and at an altitude of 1530 feet, the aircraft levelled off momentarily. Shortly afterward, the aircraft began to deviate above the 3.2° FPA (Appendix A).

At 1427:26, the PM moved the flap selector lever from flaps 2 to flaps 3 a second time, again without communicating the selection or acknowledging that the speed was correct for the flap setting. Owing to the thrust increase described above, the airspeed increased to greater than the 185 knots maximum speed for flaps 3 selection, reaching 193 knots.

Within 3 seconds of the flaps 3 selection, the flaps extended to the flaps 3 position and the flight data recorder (FDR) recorded a master warning. A continuously repetitive chime, consistent with the flap overspeed warning, sounded for about 3.5 seconds.

At 1427:29, the flight crew changed the FPA on the FCU from 0° to 3.2°. As a result, the FMA lateral and vertical modes returned to TRK and FPA, respectively; the autothrust changed from THR CLB to SPEED mode.

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13 The Air Canada Rouge *Aircraft Operating Manual A319* indicates that the maximum airspeed is 200 knots at flaps position 2, and 185 knots at flaps position 3.

At 1427:32, the PM again momentarily retracted the flaps to the flaps 2 position. The PF disengaged the autothrust (by pressing the instinctive[14] disconnect pushbutton and moving thrust levers to idle). The PM communicated to the PF that the flaps were at position 2.

At 1427:38, the PM moved the flap lever to the flaps 3 position for the final time, where it remained for the landing. The PM advised the PF of this flap selection. The aircraft was descending through 1420 feet, with an airspeed of 182 knots, thrust levers at idle, and autothrust off. The vertical rate of descent was 300 fpm.

At 1427:42, the PF stated that the aircraft was too high and that he was correcting, then stated that the autothrust was off. The PM did not hear the statement that the autothrust was off. The aircraft continued on the approach, and the rate of descent increased to 1400 fpm. During this time, the aircraft descended and began to converge on the 3.2° FPA followed by the FPA for the 2.95° PAPI. The aircraft was established on the PAPI at approximately 1428:24 (1.9 nm from the runway).

At 1427:52, the PM initiated the callouts associated with the landing flap selection portion of the final approach and landing check. The PM called out "autothrust," which is the first callout item. The PF did not immediately respond, but shortly afterward he initiated a dialogue regarding the FAF and the missed-approach altitude, interrupting the checklist. The PF requested that the PM dial in the missed-approach track and altitude. The pre-landing check was not completed. The autothrust remained off, and thrust levers remained at idle.

During the exchange between the PF and PM, the aircraft continued from 3.8 nm to 1.9 nm from the runway, descended from 1430 feet to 670 feet, and decelerated from 177 knots to 160 knots. The aircraft also descended through the Air Canada Rouge 500-foot arrival gate (100 feet above minimum descent altitude) used for the stabilized approach criteria, at which time the stabilized approach check must be completed, according to the Air Canada Rouge SOPs. The check was not done at this time.

At 1428:34, when the aircraft was 1.5 nm from the threshold, at 500 feet, with an airspeed of 155 knots, the flight crew acknowledged that the aircraft was back on profile.

At 1428:44, the flight warning computer (FWC) issued an aural alert of "four hundred."

At 1428:48, the PF made the 500-foot stable approach call, which included "a hundred above, stable, minimums, runway in sight." The aircraft was approximately 1 nm from the runway, at 370 feet, with an airspeed of 146 knots (V_{APP} plus 12 knots). The engines were at idle thrust, with autothrust off. At that time, the aircraft did not meet the Air Canada Rouge stabilized approach criteria, as the airspeed was high, the thrust setting was at idle, and the

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14 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), Supplementary Techniques, Power Plant, 1.03.71, p. 2. Pressing the instinctive disconnect pushbutton (located on the thrust levers) causes the engines to immediately develop thrust corresponding to the position of their thrust levers.

landing checklist was incomplete. The stabilized approach criteria will be explained in greater detail later in this report.

At 1429:05, the flight crew confirmed with each other that they were cleared to land. The aircraft was approximately 0.5 nm from the threshold; the airspeed was decreasing through 134 knots (V_{APP}). The aircraft was descending through approximately 200 feet above ground level (agl) with a pitch of 5.6° nose-up, and engine thrust was at idle; the rate of descent was 570 fpm. At 1429:13, the FWC emitted an aural warning of "one hundred."

At 1429:15, approximately 0.2 nm from the threshold, the PF applied nose-up side-stick input, consistent with the landing flare, as the aircraft descended through 80 feet agl. The airspeed was 123 knots (11 knots below V_{APP}), the rate of descent was approximately 650 fpm, and the calculated true angle of attack (AOA) was approximately 9.9°. The normal technique is to reach a 30-foot flare height at V_{APP} in a stabilized condition and to begin a progressive flare while simultaneously closing the thrust levers, in order to be at idle before touchdown.[15]

At 1429:17, the FWC issued the aural alert "fifty."

At 1429:18, at 40 feet agl, the airspeed was decreasing through approximately 115 knots (19 knots below V_{APP}). The pitch angle had stabilized at 9.8° nose-up, the rate of descent was approximately 860 fpm, and the calculated true AOA was approximately 13.8°. At this point, the aircraft was in a low-energy state. The FWC issued an alert of "thirty," and the thrust levers were momentarily advanced to maximum take-off thrust (take-off/go-around [TOGA]) power. The engine thrust responded but increased by only 4% before the aircraft touched down.

During the flare, with full nose-up side-stick input, the nose-up pitch command increased, the calculated true AOA reached a maximum of approximately 15.3°, and the elevator position oscillated between 1° and 5° nose-up. This sequence is consistent with alpha protection, a mode of the aircraft's high-AOA protection system that enables the PF to pull the side-stick full aft and achieve the best possible lift, minimizing the risk of aerodynamic stall or control loss.[16] The pitch attitude subsequently began to decrease from the maximum 9.8° nose-up value before touchdown.

At 1429:21, the aircraft touched down hard, with a vertical load factor of 3.12*g*. The airspeed was 108 knots, and the pitch angle was 7.7° nose-up. At main gear touchdown, the calculated distance past the displaced threshold[17] was approximately 125 feet.

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15 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), Standard Operating Procedures, Normal Landing, 1.04.13, p. 1.

16 *Air Canada A319 Flight Crew Training Manual* (29 July 2011), Normal Operations, Operational Philosophy, Flight Controls, p. 10.

17 Displaced threshold refers to a threshold that is not located at the extremity of a runway.

Immediately following the touchdown, the ground spoiler was extended and the autobrake was activated normally, and the flight crew applied reverse thrust. The aircraft taxied off the runway without further incident.

The flight crew reported the hard landing, after which an initial inspection of the aircraft was performed. After a review of the FDR data, Air Canada Rouge maintenance personnel inspected the aircraft.

1.2 *Injuries to persons*

Table 1. Injuries to persons

	Crew	Passengers	Others	Total
Fatal	–	–	–	–
Serious	–	–	–	–
Minor/None	6	131	–	137
Total	6	131	–	137

1.3 *Damage to aircraft*

The aircraft did not sustain structural damage or damage that adversely affected its flight characteristics. However, it was determined that the left and right main landing gear had been subjected to a high load exceedance. As a result, a flight permit was obtained from Airbus and Transport Canada (TC) to fly the aircraft to Miami, Florida, with the landing gear down. Both left and right shock absorbers were replaced as a precaution, as recommended by Airbus.

1.4 *Other damage*

Not applicable.

1.5 *Personnel information*

1.5.1 *Flight crew*

The flight crew was certified and qualified within existing regulations. The occurrence flight was the first time the crew had flown together.

The PF had approximately 10 000 hours of total flight time, including 4200 hours on the aircraft type, 500 of which were as pilot-in-command. In October 2013, the PF was hired by Air Canada Rouge as a captain on the Airbus A319. Previously, he had been employed by Air Canada mainline since March 2006. He had received initial training as a first officer on the A319/A320 in 2008 and had completed upgrade training to become a captain in December 2013.

The PM had approximately 12 000 hours of total flight time, including 475 hours on the Airbus A319/A320, all of which were as second-in-command. His employment with Air

Canada Rouge began in October 2013. Previously, he had been employed by Air Canada mainline since March 2013. The PM's biannual recurrent training had been conducted in October 2013.

1.6 Aircraft information

1.6.1 General

Table 2. Aircraft information

Manufacturer	Airbus Industrie
Type and model	Airbus A319-114
Year of manufacture	1997
Serial no.	0697
Registered to	Air Canada Rouge LP
Engine type (number of engines)	CFM International CFM56-5A5 (2)
Maximum allowable take-off weight	154 300 pounds
Number of passenger seats	136
Country of manufacture	France

Records indicate that the aircraft was certified, equipped, and maintained in accordance with existing regulations and approved procedures. Nothing was found to indicate that the aircraft encountered any type of system malfunction during the flight.

1.6.2 Autothrust system

The Airbus A319 autothrust system has console-mounted levers to control engine thrust. Each lever has 5 detents.[18] The levers remain in the selected detent until moved by the flight crew; they do not move in response to changes in engine thrust. When the autothrust is active, A/THR is indicated in white on the FMA.

Thrust is controlled automatically when the autothrust is active; otherwise, it is controlled manually by the pilot. As explained in the Air Canada Rouge *Aircraft Operating Manual* (AOM), "With A/THR disconnected, thrust control between full reverse […] and maximum takeoff or go-around thrust is entirely conventional. TLA (Thrust Lever Angle) determines the thrust demanded."[19]

When the autothrust system is active, in THRUST mode (e.g., CLB or IDLE), it maintains a specific fixed thrust level. In SPEED/MACH mode, "the Autothrust varies the thrust so as to

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18 The five detents are as follows: maximum take-off thrust (TOGA), maximum continuous thrust (FLX MCT), maximum climb thrust (CL), idle thrust (IDLE), and maximum reverse thrust (MAX REV).

19 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), Supplementary Techniques, Power Plant, 1.03.71, p. 1.

maintain target speed, when the AP/FD [autopilot/flight director] guides the aircraft on a given trajectory (e.g., V/S [vertical speed], ALT [altitude], G/S [glideslope] modes)."[20]

> Autothrust disconnection occurs when:
>
> - The A/THR fails, or
> - The FCU's A/THR pushbutton is pressed, or
> - The thrust lever(s)' instinctive disconnect button is pressed, or
> - Both thrust levers are set to IDLE.21

1.6.3 Autothrust warnings/indications

The autothrust can be monitored on the primary flight display (PFD) "by checking the active mode on the FMA, the current speed versus the target speed, and the speed trend vector on the speed scale."[22] It can also be monitored on the ECAM [electronic centralized aircraft monitor] "by checking the thrust command symbols on the engine thrust indication ."[23]

According to the Airbus Industrie *Aircraft Maintenance Manual*,[24] after the autothrust is disengaged, the following warnings or indications will be displayed:

> - MASTER CAUTION lights in amber on the glare-shield (off after 3 seconds)
> - A/THR OFF amber message in the memo area of the upper display of the ECAM system (disconnected using the instinctive button) (message disappears after 9 seconds)
> - AUTO FLT – A/THR OFF amber message in the warning area of the display unit of the ECAM (disconnect other than instinctive button)
> - Aural warning (single chime)

1.6.4 Low-energy warning

The energy condition of an aircraft is a function of the following primary flight parameters:

- airspeed and airspeed trend;
- altitude, vertical speed, or flight path angle;
- drag (caused by speed brakes, slats/flaps, and landing gear); and
- thrust.

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[20] Ibid., Standard Operating Procedures, 1.04.00, p. 5.

[21] Ibid., Supplementary Techniques, Power Plant, 1.03.71, p. 2.

[22] Ibid., Standard Operating Procedures, 1.04.00, p. 5.

[23] Ibid.

[24] Airbus Industrie, *Aircraft Maintenance Manual* (AMM), 22-31-00, pp. 15–16.

The A319 is equipped with an aural low-energy warning. "The 'SPEED SPEED SPEED' synthetic voice sounds every 5 seconds whenever the aircraft energy goes below a threshold under which thrust must be increased."[25] According to the AOM, the flight crew action is "Increase the thrust until the warning stops and, depending on the circumstances, adjust the pitch accordingly."[26] The warning will sound if the flap configuration is 2 or higher, but is deactivated if the aircraft is below 100 feet agl.

1.6.5 Flight control unit

The operation of the aircraft's FCU is detailed in the Airbus A319 *Flight Crew Operating Manual*. The FCU is the primary interface between the flight crew and the auto-flight system. It is located in the centre area of the glareshield. Flight crew operation of the FCU can modify any current flight parameters on a temporary basis and can also be used to select operational modes for the autopilot, flight director, and autothrust systems. Autopilot guidance modes can be selected on the FCU (Figure 3). The specific mode is displayed on the FMA portion of the PFD.

The FCU has 4 knobs for the selection of (1) speed, (2) heading/track, (3) altitude, and (4) vertical speed/flight path angle. When pushed, the knobs switch each aspect to a managed mode in which the aircraft is guided by the FMGS. When pulled, the knobs provide the flight crew with control over each aspect. Thus the flight crew can override any aspect of the managed guidance by selecting the desired speed, heading/track, altitude, or vertical speed/flight path angle, and pulling the knob to activate the selection.

The altitude selector (ALT/SEL) changes the altitude displayed in the ALT window. When the selected altitude is above the current aircraft altitude and the ALT/SEL is pulled, the mode will change to OP CLB. As a result, the aircraft will begin to climb and the autothrust will increase the engine thrust as necessary. This sequence led to the thrust increase that occurred at 1427:22, described in section 1.1.

The vertical speed/flight path angle knob, when rotated, changes the V/S or FPA in the V/S, FPA window. Pulling the selector engages the V/S or FPA function; the aircraft is then guided along the selected vertical path. Pushing the knob levels the aircraft off at the current altitude.

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25 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), Abnormals, Auto Flight, 1.02.22, p. 7.

26 Ibid.

Figure 3. Flight control unit, showing the altitude selector knob (second from right), and the vertical speed/flight path angle selector knob (far right) (Source: Federal Aviation Administration, Accident Overview, Indian Airlines Flight 605, Airbus A320-231, VT-EPN)

1.7 Meteorological information

The surface aviation routine weather report (METAR) for MKJS issued at 1400 (29 minutes before the landing) indicated winds from 060° true (T) at 17 knots, with visibility of 6 statute miles (sm) or more, dropping to 1 sm to the southwest in the vicinity of rain showers, scattered clouds at 2000 feet, towering cumulus clouds, and temperature of 30°C.

The METAR issued at 1500 (31 minutes after the landing) indicated winds from 080°T at 15 knots, with visibility of 6 sm or more, dropping to 3 sm to the southwest in the vicinity of rain showers, few clouds at 1800 feet, few clouds at 2000 feet, towering cumulus clouds, and temperature of 30°C.

1.8 Aids to navigation

MKJS was served by the following approaches: ILS/DME Runway 07, VOR/DME Runway 07, RNAV Runway 07, and RNAV Runway 25. At the time of the occurrence, the ILS was out of service, which had been reported in a NOTAM.

1.9 Communications

The flight crew communicated effectively with various ATC agencies during the flight, and the content of those communications did not contribute negatively to the occurrence. For details regarding ATC communication during the approach and its effect on timing and flight crew interaction, refer to sections 1.1 and 2.0.

1.10 Aerodrome information

MKJS has 1 runway (Runway 07/25) with an overall length of 8735 feet and a width of 151 feet. An ILS is fitted on the primary approach (Runway 07). The threshold of Runway 07 is displaced by 300 feet. The Runway 07 track is 068° magnetic, and its threshold elevation is 7 feet asl (Appendix B).

Runway 07 is equipped with a 2.95° PAPI for vertical guidance. The PAPI consists of 2 sets of wing bars, each containing 4 lights, located on either side of the runway.

1.11 Flight recorders

The FDR download file was received from the aircraft operator for analysis. It contained approximately 26.4 hours of recorded flight data, including data for the occurrence flight and 6 previous flights. The aircraft was also equipped with a solid-state CVR (Honeywell 980-6022-001) with a minimum recording capacity of 120 minutes. Its data were downloaded successfully and included good-quality audio recordings of the 135 minutes before touchdown and 9 minutes after touchdown.

1.12 Wreckage and impact information

Not applicable.

1.13 Medical and pathological information

Not applicable.

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 report in support of this investigation:

- LP093/2014 – Flight Data Recorder Analysis

1.17 Organizational and management information

1.17.1 General

Air Canada Rouge is a wholly owned subsidiary of Air Canada. It became a *Canadian Aviation Regulations* (CARs) Subpart 705 operator in June 2013 and had its first revenue flight in July of that year. The airline is fully integrated into the Air Canada mainline and Air Canada Express networks. According to the TC Canadian Civil Aircraft Register, the company operates 20 Airbus A319 and 14 Boeing 767 aircraft.

1.17.2 Flight crew training

Air Canada uses the advanced qualification program training system that is common among larger airlines. This training system does not involve traditional pilot proficiency checks following training but instead includes validation sessions to assess the trainee. However, Air Canada Rouge uses the traditional method, in which a pilot proficiency check follows the requisite training.

Although the validation of trainees is accomplished differently at Air Canada Rouge than at Air Canada, the training is similar. The session summaries for each training event are identical at both airlines. The autothrust simulator training is the same for both Air Canada and Air Canada Rouge flight crews.

At the time of the occurrence, simulator training in autothrust-off approaches was part of the training syllabus at both airlines for flight crew members receiving initial type training and recurrent training. As Air Canada Rouge has a 36-month recurrent training cycle, the items in the initial training syllabus are covered again at some point in the 36-month period.

The PF had completed the first of the 6 recurrent training modules in the 36-month matrix, and the PM was not yet required to complete the first module. Both training schedules were in accordance with company policy and current regulations.

When the PF was upgraded to captain, he received the upgrade training that is provided to flight crew who are currently qualified on the aircraft type as first officer and are upgrading to captain. There is no training in autothrust-off approaches in the upgrade course, and none is required by regulation. The PF had completed training in non-autothrust approaches during his initial A319/A320 training in 2008.

Crew resource management (CRM), including threat and error management, forms part of the initial flight-crew training syllabus at Air Canada Rouge, and a refresher course is given during recurrent training.

At the time of the occurrence, Air Canada Rouge did not provide flight crews with simulator training to recognize unstable approaches, nor was such training required by regulation.

1.17.3 Air Canada Rouge standard operating procedures

The Air Canada Rouge *Flight Operations Manual* (FOM) is the central component of the *Company Operations Manual*. The FOM "contains Air Canada rouge's procedures and policies which are aligned with regulatory requirements and international standards to ensure the highest level of safety, efficiency and reliability in all of [its] operations."[27] According to Air Canada Rouge's FOM, "Information in the FOM applies to all flight operations, except when superseded by an AOM."[28] The FOM states that, "except for when the flight crew determines

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27 Air Canada Rouge, *Flight Operations Manual* (FOM) (17 February 2014), 1.1 Preface.

28 Ibid., 1.7.2 Scope.

that a deviation is required for the immediate interests of flight or passenger safety, all flight crew members shall[29] comply with the SOPs."[30]

The FOM describes critical phases of flight as follows:

> Critical phases of flight include all ground movement, flight below 10 000 feet AAE [above airport elevation] on departure, and flight from Top of Descent (TOD) on arrival. During critical phases of flight the Pilot-in-Command shall enforce the critical phase of flight policy as follows:
>
> 1. Only required operational conversation shall be conducted; and
>
> 2. Activities shall be restricted to essential operational activities; and
>
> 3. Communications with parties outside of the flight deck shall be completed using headsets and boom microphones except if MEL [minimum equipment list] relief is being applied; and
>
> 4. External communications shall be restricted to essential operational communications; and
>
> 5. The P-EFB [portable electronic flight bag] shall be stowed during all critical phases of flight except when on descent above 10,000 feet AAE. When airborne and below 10,000 feet AAE, the P-EFB shall only be used when required for safety of flight.[31]

According to the FOM,

> The purpose of the arrival and approach briefing is to enhance situational awareness and clarify expectations. Arrival and approach briefings are required for all approaches including visual approaches.
>
> The aircraft AOMs contain sample approach briefings which shall be used by Flight Crews to conduct arrival and approach briefings.[…]
>
> Following the first approach briefing of each crew cycle the Flight Crew shall review the go-around procedure from the point where the PF calls "Go-around, flaps" to the point where climb thrust would be selected.[32]

The sample briefings referred to in the FOM address the minimum requirements of the approach briefings. They include the go-around procedures and the published missed-approach procedures.

According to Air Canada Rouge SOPs, the PM must check the airspeed before all flap selections "to ensure that the called[-]for flap setting is within the correct speed range. If within the correct speed range the PM calls 'SPEED CHECKED' then selects the requested

29 "'Shall, must, will, has to, is to' means that application of the criteria is mandatory." Ibid., 1.7.7.2 Word Meanings.

30 Ibid., 6.2 Standard Operating Procedure (SOP) Compliance.

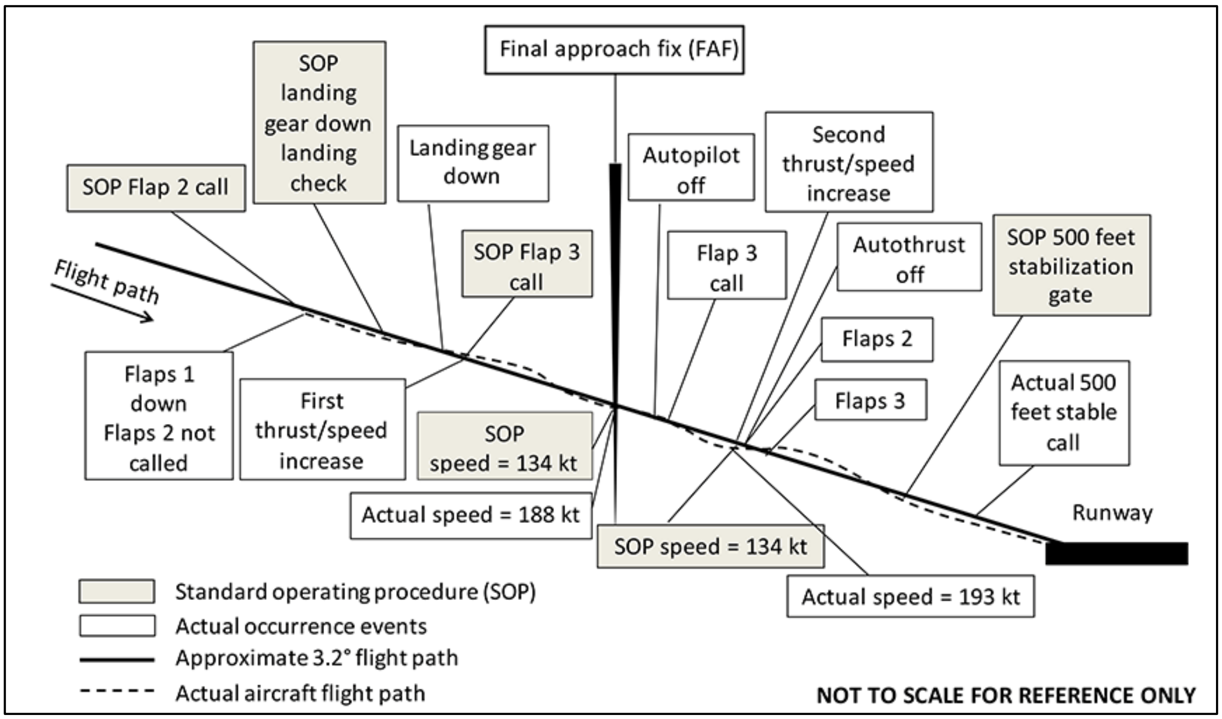
31 Ibid., 7.1.7 Critical Phases of Flight.

32 Ibid., 8.9.10.3 Arrival and Approach Briefing.

[…] Flap setting."[33] The SOPs then specify that the verbal call is made by the PM "after observing the proper extension of the […] Flap configuration."[34] During the approach in this occurrence, the required speed calls for flap selection were not carried out.

Several other deviations from the SOPs occurred during the approach. The Air Canada Rouge SOPs for flap and gear selection, calls, and landing checks during the final approach segment are compared with the actual occurrence sequence in Figure 4. For a more comprehensive table, see Appendix C. In addition, the flight crew did not announce or cross-check several FMA changes, as required by the SOPs.

Figure 4. Actual occurrence events compared with Air Canada Rouge standard operating procedures (SOP)



The Air Canada Rouge AOM states the following regarding autopilot/autothrust operation:

> Auto-thrust should[35] be kept active from the Thrust Reduction Altitude after Take-off to just prior to the "RETARD" call during the flare, unless heavy turbulence conditions are encountered.
>
> When flight conditions and workload permit hand flying of the aircraft and the use of manual thrust is encouraged.[36]

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33 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), 1.04.11 Standard Operating Procedures, Approach, p. 3.

34 Ibid.

35 "'Should' means that application of the criteria is strongly recommended." Air Canada Rouge, *Flight Operations Manual*, 1.7.7.2 Word Meanings.

36 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), 1.04.00 Standard Operating Procedures, Use of Autopilot and Autothrust, p. 2.

> All active FMA modifications [boxed] must be announced by the PF from the beginning of the take-off roll to the point of the "LANDING" call. All FMA calls are cross-checked by the PM on the PFD.[37]

Regarding the selection of flaps and landing gear, the AOM states:

> The order in which Flaps and Gear are selected may[38] vary due to circumstance. As a general rule it is desirable to use the Gear and Flaps judiciously in order not to create an undue amount of drag with an increase in power. Flap 1, Flap 2, and Landing Gear selections are routinely made prior to the FAF and the Landing Flap may be delayed according to conditions.[39]

Regarding significant deviations, the Air Canada Rouge FOM states, “The PM shall alert the PF by calling ‘Glideslope,’ ‘Localizer,’ or ‘Airspeed’ when a significant deviation is observed during an approach or when a flag or warning is observed.”[40]

In addition, the Air Canada Rouge AOM contains flight crew calls regarding deviations from flight parameters, which include airspeed deviations of more than 10 knots above target airspeed or more than 5 knots below target airspeed, vertical speed greater than 1000 fpm, bank angles greater than 7°, and pitch attitudes lower than −2.5° or greater than 10°.[41]

1.17.4 Air Canada Rouge stable approach policy

At the time of the occurrence, the Air Canada Rouge stable approach policy differed, in part, from that recommended by the Flight Safety Foundation (FSF) (section 1.18.2).

> Air Canada rouge Stable Approach Policy is built around an Arrival Gate concept whereby a flight shall not continue the approach unless the required criteria for each Arrival Gate are met. There are two Arrival Gates for every approach; the first is the FAF (or FAF equivalent), the second Arrival Gate is at 500 feet AGL (or 100' above minimums, whichever is higher). A Go-around is mandatory if the criteria for each Arrival Gate is not met [*sic*].[42]

The Air Canada Rouge criteria for a stabilized approach at the FAF arrival gate did not include several of the FSF-recommended criteria, including airspeed and sink rate,

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37 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), 1.04.00 Standard Operating Procedures, Use of Autopilot and Autothrust, p. 3.

38 According to Air Canada Rouge, *Flight Operations Manual*, 1.7.7.2 Word Meanings, “‘May’ means that application of the criteria is optional.”.

39 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), 1.04.11 Standard Operating Procedures, Approach, p. 1.

40 Air Canada Rouge, *Flight Operations Manual* (17 February 2014), 8.11.3 Monitoring Deviations during Approach.

41 Air Canada Rouge, *Aircraft Operating Manual A319* (10 May 2013), 1.04.11 Standard Operating Procedures, Approach, p. 29.

42 Air Canada Rouge, *Flight Operations Manual* (17 February 2014), 8.11.6 Stabilized Approach Criteria.

configuration, power settings, briefings or checklist completion. Aircraft were required to meet the recommended criteria only at the 500-foot gate, regardless of weather conditions.

1.17.5 Air Canada Rouge stabilized approach criteria: final approach fix arrival gate

The Air Canada Rouge FOM described the company's stabilized approach criteria for the FAF arrival gate as follows:

> No flight shall continue an approach past the FAF Arrival Gate unless it is being flown in a way that ensures the Stable Approach Criteria will be met by the 500 foot Arrival Gate.
>
> The tracking requirements are applied to the various approaches as follows:
>
> 1. Precision approach — the aircraft must be on the localizer and glide path; and
>
> 2. Non-precision approach (NPA) — the aircraft must be on the inbound course and on the descent profile as defined by FPA, Vertical Speed, or FMS [flight management system]/FMGS determined profile; and
>
> 3. Published visual approach — on the inbound course and flying as close as allowed to a 3° descent path to the runway while following vertical guidance when provided, or visual approach slope indicators (i.e. PAPI, VASIS [visual approach slope indicator] or HGS [heads-up guidance system]); and
>
> 4. Other Visual approaches — on the extended centerline of the runway and flying as close as able to a 3° descent path to the runway and using visual approach slope indicators (i.e. PAPI, VASIS or HGS) if available.
>
> Flight Crews shall use 1,000 feet AGL as the FAF Arrival Gate in the absence of a FAF (or FAF equivalent) and when flying a Visual Transition or Maneuver from an instrument approach.[43]

1.17.6 Air Canada Rouge stabilized approach criteria: 500-foot arrival gate

The Air Canada Rouge FOM described the company's stabilized approach criteria for the 500-foot arrival gate as follows:

> No flight shall continue an approach past the 500 foot Arrival Gate (or 100 feet above minimums, whichever is higher) unless the following Stable Approach Criteria are met:
>
> 1. Flaps and landing gear are in the landing configuration; and
>
> 2. Landing Checklist completed; and
>
> 3. Indicated airspeed within plus 10 knots to minus 5 knots of target airspeed (Airbus - target airspeed is Ground Speed Mini when active); and
>
> 4. Thrust stabilized, usually above idle, to maintain the target approach speed along the desired flight path; and

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[43] Air Canada Rouge, *Flight Operations Manual* (17 February 2014), 8.11.6.1 FAF Arrival Gate.

> 5. Established on the correct vertical approach path and where applicable, remaining within ½ scale deflection of the guidance used for an instrument approach or, for a visual approach, established on the correct approach slope as indicated by visual approach slope indicators (i.e., VASIS, PAPI or HGS); and
>
> 6. Rate of descent not in excess of 1,000 fpm unless required to maintain the published constant descent path (e.g., glideslope, VASIS, calculated descent rates, etc.). If an approach requires a rate of descent greater than 1,000 fpm, a special briefing should be conducted; and
>
> 7. Established on the correct lateral approach path and where applicable, remaining within ½ scale deflection of course deviation indications for VOR, localizer approaches and five degrees of track for NDB [non-directional beacon] approaches.[44]

1.17.7 Air Canada Rouge stabilized approach criteria: below 500 feet

The Air Canada Rouge FOM described the company's stabilized approach criteria below 500 feet as follows:

> The aircraft must continue to meet the Stable Approach Criteria below 500 feet and be in a position over the runway threshold to make a normal landing within the Touchdown Zone. The PM shall monitor flight instrument indications for Stable Approach Criteria compliance through to touchdown. If these criteria are not maintained at and below 500 feet AGL, the "Unstabilized" call shall be made, even if a "Stable" call had been made earlier. A Go-around shall be carried out anytime the "Unstabilized" call is made.[45]

According to the Air Canada Rouge stabilized approach criteria, the aircraft was stable at the FAF arrival gate. However, the airspeed was 54 knots faster than V_{APP}, and the aircraft was not configured with the proper flaps settings as per the Air Canada Rouge SOPs. The aircraft was not stable at the 500-foot arrival gate (actually 710 feet as per the SOPs) because of its excessive airspeed, vertical speed deviations, incomplete landing checklist, and unstabilized thrust.

1.17.8 Safety management system and flight data monitoring

Air Canada Rouge has implemented a safety management system (SMS) "in accordance with TC guidance material, CARs, and IATA [International Air Transport Association] International Operational Safety Audit (IOSA) Standards and Recommended Practices."[46]

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[44] Air Canada Rouge, *Flight Operations Manual* (17 February 2014), 8.11.6.2 500 Foot Arrival Gate.

[45] Ibid., 8.11.6.3 Stable Approach Criteria Below 500 feet.

[46] Ibid., 2.1 Safety Management System.

Pursuant to Air Canada Rouge policies and standard SMS practices, the company has a non-punitive reporting policy. "It is the responsibility of all employees to report hazards, incidents, and accidents that have an impact on the operational safety and integrity of Air Canada rouge."[47]

Air safety reports (ASR) are used by flight crew to report such incidents and hazards. The reports "are de-identified and accessible by all levels of management who are required to regularly review, provide feedback, and monitor the progress of analysis and investigations."[48]

The Air Canada Rouge safety program includes compulsory reportable events, such as unstable approaches and go-arounds. Flight crews are obliged to submit an ASR any time a reportable event occurs. A review of the ASR database indicated that flight crews had reported unstable approaches and go-arounds, as intended under the SMS.

In addition to the SMS, Air Canada Rouge also uses flight data monitoring (FDM) and flight data analysis as part of its safety program. Flight data from regularly scheduled flights are downloaded from the aircraft quick-access recorder at scheduled flight-hour intervals. The data are subsequently analyzed to locate specific, predetermined aircraft flight parameters and data sets, including those associated with unstable approaches.

Air Canada Rouge records the incidence of unstable approaches through the FDM system, the details of which are reported internally on a monthly basis. The data are shared with Air Canada to identify issues that both carriers have in common so that corrective actions can be applied.

1.18 Additional information

1.18.1 Unstable approaches

As shown in previous investigations by the TSB and by agencies in other countries, unstable approaches present a high risk to safe flight operations. While defences[49] are available to air carriers to mitigate the risks associated with unstable approaches, not all defences are employed by all operators. These defences are mainly administrative and include

- A company stabilized-approach policy, including no-fault go-around policy;
- Operationalized stable approach criteria and standard operating procedures (SOPs), including crew phraseology;

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[47] Ibid., 2.5 Reporting of Hazards, Incidents, and Accidents.

[48] Ibid., 2.5.1 Air Safety Report (ASR).

[49] Flight Safety Foundation, Approach-and-Landing Accident Reduction (ALAR) Task Force, *FSF ALAR Tool Kit* (2009), Briefing Note 7.1, Stabilized Approach.

- Effective crew resource management (CRM), including empowering of first officers to take control in an unsafe situation;
- Use of flight data monitoring (FDM) programs to monitor SOP compliance with stabilized approach criteria;
- Use of line-oriented safety audits (LOSA) or other means, such as proficiency and line checks, to assess CRM practices and identify crew adaptations of SOPs;
- Non-punitive reporting systems (to report occurrences or unsafe practices);
- Use of terrain awareness and warning systems (TAWS).[50]

Research by the FSF has concluded[51] that 3.5% to 4% of approaches are unstable. Of these, 97% are continued to a landing, with only 3% resulting in a go-around. To put these figures in context, in 2012 there were 24.4 million flights worldwide in a fleet of civilian, commercial, Western-built jet airplanes heavier than 60 000 pounds. This means that between 854 000 and 976 000 of those flights terminated with an unstable approach, and approximately 828 000 to 945 000 continued to a landing. The potential negative consequences of continuing an unstable approach to a landing include controlled flight into terrain (CFIT), runway overruns, landing short of the runway, and tail-strike accidents.

The FSF has found that approaches conducted either high/fast or low/slow were a causal factor in about two-thirds of approach-and-landing accidents and incidents worldwide from 1984 through 1997.[52] As well, flight-handling difficulties (i.e., crew management of airspeed, altitude, and rate of descent) were found to be a causal factor in almost half of the occurrences studied, with those occurrences involving scenarios that included improper use of automation.[53]

The results of a study of pilots' experiences conducting unstable approaches and go-arounds were reported in the April 2013 issue of *Aero Safety World*.[54] More than 2000 pilots were asked to provide detailed accounts of recent experiences with approaches that were unstable below the stabilized approach height and that either resulted in a go-around or were continued to a landing. The study found that the decision to continue with an unstable

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50 Transportation Safety Board (TSB) Aviation Investigation Report A11H0002 (20 August 2011), section 4.2: Safety action required.

51 Flight Safety Foundation, "Failure to Mitigate," Aero Safety World (February 2013), available at: https://flightsafety.org/asw-article/failure-to-mitigate/ (last accessed on 09 November 2016).

52 Flight Safety Foundation, "Killers in Aviation: FSF Task Force Presents Facts About Approach-and-landing and Controlled-flight-into-terrain Accidents," *Flight Safety Digest*, Vol. 17 (November–December 1998) and Vol. 18 (January–February 1999), pp. 1–121.

53 Ibid.

54 J.M. Smith, D.W. Jamieson, and W.F. Curtis, "Why do we forgo the go-around?", *Aero Safety World* (April 2013), available at: https://flightsafety.org/asw-article/why-do-we-forgo-the-go-around/ (last accessed on 09 November 2016).

approach was associated with lower levels of perceived risk associated with such an approach.

In particular, the study found that pilots were more likely to continue with unstable approaches in visual meteorological conditions and in the absence of environmental factors that might increase operational complexity, such as wind shear, turbulence, and contaminated runways. The authors suggest that these factors increase the pilot's perception that an approach can be salvaged, reducing the perceived risk associated with continuing the approach. The study also found that fewer unstable approaches were continued to a landing in cockpit environments that were described as more supportive, less judgmental, and more accepting of challenge, and in which there were more frequent conversations about operational and flight risks.

Numerous TSB investigations[55] have shown that non-adherence to company SOPs related to stable approaches is not unique to Air Canada Rouge.

1.18.2 Recommended elements of a stable approach

Following the recommendations of its Approach-and-Landing Accident Reduction (ALAR) Task Force, the FSF created and distributed an *ALAR Tool Kit* intended to reduce the number of approach-and-landing accidents. In Briefing Note 7.1, Stabilized Approach, the Tool Kit defines a stabilized approach, including the minimum altitude at which an approach should be stabilized, as well as all of the elements of a stabilized approach.

Specific limits on excessive deviation from 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 calls are faster and more accurate.

The FSF recommendations have been adopted by several airlines in Canada and have become a recognized standard for stabilized approaches. According to the FSF,

> All flights must be stabilized by 1,000 ft above airport elevation in instrument meteorological conditions (IMC) and by 500 ft above airport elevation in visual meteorological conditions (VMC). An approach is stabilized when all of the following criteria are met:
>
> 1. The aircraft is on the correct flight path;
>
> 2. Only small changes in heading/pitch are required to maintain the correct flight path;
>
> 3. The aircraft speed is not more than V_{REF}[56] + 20 kt [knots] indicated airspeed and not less than V_{REF};

55 TSB aviation investigation reports A07Q0213, A11H0002, A11O0098, A12P0034, A12Q0216, A13O0098, and A14W0127.

56 V_{REF} is the reference speed used for normal final approach. Air Canada Rouge, *Aircraft Operating Manual A319*, Volume 1 (10 May 2013), Performance, section 1.05.00, p. 5.

> 4. The aircraft is in the correct landing configuration;
>
> 5. Sink rate is no greater than 1,000 fpm; if an approach requires a sink rate greater than 1,000 fpm, a special briefing should be conducted;
>
> 6. Power setting is appropriate for the aircraft configuration and is not below the minimum power for approach as defined by the aircraft operating manual;
>
> 7. All briefings and checklists have been conducted;
>
> 8. Specific types of approaches are stabilized if they also fulfill the following: instrument landing system (ILS) approaches must be flown within one dot of the glideslope and localizer; a Category II or Category III ILS approach must be flown within the expanded localizer band; during a circling approach, wings should be level on final when the aircraft reaches 300 ft above airport elevation; and,
>
> 9. Unique approach procedures or abnormal conditions requiring a deviation from the above elements of a stabilized approach require a special briefing.
>
> An approach that becomes unstabilized below 1,000 ft above airport elevation in IMC or below 500 ft above airport elevation in VMC requires an immediate go-around.[57]

The FSF International Advisory Committee has completed a recent study regarding stabilized approaches and industry best practices. As a result, the FSF is currently reviewing its recommendations and may make modifications.

1.18.3 Training regulations

CARs Subpart 705.124(1) requires the following:

> Every air operator shall establish and maintain a training program that is
>
> (a) designed to ensure that each person who receives training acquires the competence to perform the person's assigned duties; and
>
> (b) approved by the Minister in accordance with the *Commercial Air Service Standards* .[58]

The *Commercial Air Service Standards* (CASS) Subpart 725.124(9)(*b*)(ii) states:

> Where the air operator seeks authorization for flight in IMC the following training in flight planning and instrument flight procedures shall be included:
>
> […]
>
> (ii) all types of instrument approaches and missed approaches in minimum visibility conditions using all levels of automation available (as applicable).[59]

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57 Flight Safety Foundation, Approach-and-Landing Accident Reduction (ALAR) Task Force, *FSF ALAR Tool Kit* (2009), Briefing Note 7.1, Stabilized Approach.

58 *Canadian Aviation Regulations* (CARs) 705.124(1).

CASS Subpart 725.124(8A)(*c*)(i) states:

> Annual training for all flight crew members for synthetic flight training device or aeroplane shall meet the following requirements:
>
> […]
>
> (i) all items for the initial training syllabus must be covered over a definite period of time (through a cycle).

1.18.4 TSB Recommendation A14-01 (25 March 2014)

On 20 August 2011, a Boeing 737-210C combi aircraft (registration C-GNWN, serial number 21067), operated by Bradley Air Services Limited under its business name First Air, was flown as First Air charter flight 6560 from Yellowknife, Northwest Territories, to Resolute Bay, Nunavut. At 1642 Coordinated Universal Time (1142 Central Daylight Time), during the approach to Runway 35T, First Air flight 6560 struck a hill about 1 nm east of the runway. The aircraft was destroyed by impact forces and an ensuing post-crash fire. Eight passengers and all 4 crew members sustained fatal injuries. The remaining 3 passengers sustained serious injuries and were rescued by Canadian military personnel, who were in Resolute Bay as part of a military exercise. The accident occurred during daylight hours.

The TSB concluded its investigation and released TSB Aviation Investigation Report A11H0002 on 25 March 2014.

In that accident, the aircraft arrived high and fast on final approach, was not configured for landing on a timely basis, had not intercepted the localizer, and was diverging to the right. This approach was not considered stabilized according to the company's stabilized approach criteria, and the situation required a go-around. Instead, the approach was continued. When the crew initiated a go-around, it was too late to avoid the impact with terrain. Unstable approaches continue to be a high risk to safe flight operations in Canada and worldwide.

Occurrences in which an unstable approach was a contributing factor demonstrate that the severity of an occurrence can range from no injuries or damage to multiple fatalities and destruction of the aircraft. In the Resolute Bay occurrence, the continuation of an unstable approach led to a CFIT accident and the loss of 12 lives. Without improvements in compliance with stable approach policies, most unstable approaches will continue to a landing, increasing the risk of CFIT and approach-and-landing accidents.

Current defences against continuing unstable approaches have proven less than adequate. In Canada, although many CARs Subpart 705 operators have voluntarily implemented FDM programs, there is no requirement to do so. First Air was not conducting FDM at the time of the Resolute Bay accident. Furthermore, FDM programs must specifically look at why unstable approaches are occurring, how crews handle them, whether crews comply with company stabilized approach criteria and procedures, and why crews continue an unstable

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[59] *Commercial Air Service Standards* (CASS) 725.124(9)(*b*)(ii).

approach to a landing. Unless further action is taken to reduce the incidence of unstable approaches that continue to a landing, the risk of approach-and-landing accidents will persist.

Therefore, 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**

In its initial response, TC indicated that a Civil Aviation Safety Alert (CASA) had been developed to encourage Subpart 705 operators to use their SMS to identify the incidence of unstable approaches and to develop mitigation measures for the risk they pose.

On 27 June 2014, TC issued CASA 2014-03. The content of the CASA reflected the information proposed in the TC response letter dated 19 June 2014. The CASA also emphasized the value of voluntary FDM programs.

Subsequently, TC

1. published an Aviation Safety Letter providing safety-awareness information concerning unstable approaches;
2. published an Internal Process Bulletin (2016-01) for targeted inspections to review the implementation of CASA 2014-03 among Subpart 705 operators; specifically, to examine an operator's assessment of unstable approaches using its SMS and, when applicable, review established mitigation strategies and the extent, type, and frequency of interventions related to unstable approaches; and
3. developed a safety-promotion presentation on unstable approaches to raise industry awareness.

The inspection campaign was to be completed by the end of summer 2016.

TC has collected the necessary data for the surveillance activities for all Subpart 705 operators. Subsequent ongoing analysis of the data regarding Internal Process Bulletin 2016-01 will allow TC to validate the impact of its CASA 2014-03.

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

Additionally, TC's ongoing safety-promotion initiatives related to unstable approaches will help maintain industry awareness.

Therefore, the response to Recommendation A14-01 was assessed as Satisfactory in Part.

1.18.5 TSB Watchlist

Unstable approaches are a 2016 Watchlist issue.

The TSB Watchlist is a list of issues posing the greatest risk to Canada's transportation system; the TSB publishes it to focus the attention of industry and regulators on the problems that need addressing today. Although this occurrence happened on foreign ground, the operator was Canadian, and the aircraft was flown by a Canadian flight crew, both of which are subject to Canadian regulations and policies.

As this occurrence demonstrates, landing accidents continue to occur. The TSB has called on TC and operators to do more to reduce the number of unstable approaches that are continued to a landing.

1.18.6 Human interaction with automation

The interaction between pilots and automated systems remains a key factor in flight safety.[60] In Briefing Note 1.2, Automation, the *FSF ALAR Tool Kit* states that

> To use the full potential of automation and to maintain situational awareness, a thorough understanding of the interaction between the pilot and the automation is required to allow the pilot to answer the following questions at any time:
>
> What did I tell the aircraft to do?
>
> Is the aircraft doing what I told it to do?
>
> What did I plan for the aircraft to do next?
>
> (The terms "tell" and "plan" in the above paragraph refer to arming or selecting modes and/or entering targets.)
>
> […]
>
> Effective monitoring of these controls and displays promotes and increases pilot awareness of the status of the system and the available guidance (for flight-path control and airspeed control). Effective monitoring of controls and displays enables the pilot to predict and to anticipate the entire sequence of flight-mode annunciations throughout successive flight phases (i.e., throughout mode changes).[61]

A variety of factors and errors can contribute to poor pilot–automation interactions, according to the FSF. Some examples of those factors and errors, which are listed in Briefing Note 1.2, include inadvertent arming of a mode or selection of an incorrect mode, failure to verify the armed mode, entering an incorrect target and failure to confirm the entered target on the display, preoccupation with FMS programming during a critical flight phase, and inadequate understanding of mode changes.[62]

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60 Flight Safety Foundation, Approach-and-Landing Accident Reduction (ALAR) Task Force, *FSF ALAR Tool Kit* (2009), Briefing Note 1.2, Automation.

61 Ibid.

62 Ibid.

Company-specific SOPs recommend and/or govern how pilots interact with the specific automation with which they fly. For automation to be used optimally, according to the FSF, emphasis should be placed on ensuring that pilots understand the autopilot/flight director and autothrust modes integration, all mode-change sequences, and the pilot–system interface, as well as on ensuring that pilots are aware of available guidance, and are alert and willing to revert to a lower level of automation or to hand-flying/manual thrust control, as required.[63]

1.18.7 Monitoring and approach stability

In the technical memorandum entitled, "Checklists and Monitoring in the Cockpit: Why Crucial Defenses Sometimes Fail," Dismukes and Berman define monitoring as "the responsibility of pilots to keep track of the aircraft's position, course, and configuration; the status of the aircraft's systems; and the actions of the other pilots in the cockpit."[64] Pilots may think of monitoring as a secondary task; however, as the authors point out, lapses in monitoring have been a factor in numerous aircraft accidents. Checklists, monitoring, and primary procedures are defences against threats and errors. However, the authors of the study explain, "these defences sometimes fail."[65]

In their study examining the reasons for such failures, the authors found that the most common primary procedure deviations involved configuration of equipment and systems; planning for, or responding to, contingencies; crew-to-crew coordination; and data entry or use of the FMS and mode control panel.[66] By contrast, in the same study, researchers also identified exemplary aspects of checklist and monitoring use, including deliberateness,[67] modelling self-discipline and professionalism, and making an error-trapping[68] routine more reliable (for example, by building in reminders).[69]

Primary procedure errors can involve errors in coordination within the crew or with ATC, in use of automation, in approach stabilization, in path and airspeed control, in configuration of

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63 Ibid.

64 R. K. Dismukes and B. Berman, Checklists and Monitoring in the Cockpit: Why Crucial Defenses Sometimes Fail (National Aeronautics and Space Administration [NASA], July 2010), p. 7.

65 Ibid., p. 19.

66 Ibid., p. 14.

67 "Deliberateness" refers to techniques that involve performing procedures in a careful and thoughtful manner (e.g., pointing to each item during checklist execution) to prevent or immediately identify errors. B. Berman and R. K. Dismukes, "Designing a Better Error Trap," *Aero Safety World* (July 2010), pp. 12-17, available at: https://flightsafety.org/asw/jul10/asw_jul10.pdf (last accessed 09 November 2016).

68 Error trapping refers to techniques in "compensating for errors so that they do not lead to accidents and incidents." Flight Safety Foundation [online at EUROCONTROL Skybrary], *The Operator's Guide to Human Factors in Aviation [OGHFA]*, available at http://www.skybrary.aero/index.php/Portal:OGHFA (last accessed on 10 October 2016).

69 R.K. Dismukes and B. Berman, *Checklists and Monitoring in the Cockpit: Why Crucial Defenses Sometimes Fail* (National Aeronautics and Space Administration [NASA], July 2010), p. 18.

systems or flight controls, or in planning and execution.[70] Such errors can be trapped with robust use of checklists and monitoring. This mitigation strategy is important because these errors can have serious consequences, including unstable approaches and approach-and-landing accidents. Deviations in checklists and monitoring and failures to trap primary procedure errors can occur because of competing task demands, poor procedure habits, and CRM failures.

The FSF has published guidance for the improvement of flight monitoring, in which it describes the challenges of and barriers to effective monitoring. Among those barriers are human performance limitations, which encompass difficulty with sustained vigilance, limitations in the abilities to multi-task and to manage distractions and interruptions, and cognitive limitations that affect what is noticed and not noticed. Time pressure is a barrier because it can exacerbate high workload and increase errors; as well, it often leads to rushing and looking without seeing. Pilots are often unaware that their monitoring performance has degraded. In addition, pilots may not have a complete or accurate understanding of all of the functions and behaviours of the automated flight system on their aircraft. As well, training and line checks may overlook the importance of monitoring and the methods to conduct monitoring effectively.[71]

1.18.8 Standard operating procedures

SOPs, including standard calls and checklists, are critical information resources that provide procedural guidance to pilots for the operation of the aircraft. They assist with pilot decision making and with crew coordination, and they provide pilots with predetermined successful solutions to various operational situations during normal operations or abnormal/emergency situations. Disciplined use of SOPs is a known mitigation strategy for unstable approaches.

1.18.9 Briefings

Briefings help both the PF (giving the briefing) and the PM (receiving and acknowledging the briefing) to understand the sequence of events and actions, the safety key points, specific threats/hazards and circumstances of the takeoff, departure, cruise segment, approach, and landing. An interactive briefing fulfills 2 important goals: it provides the PF and the PM with an opportunity to share a common action plan, and set priorities and share tasks. Briefings are a known mitigation strategy for unstable approaches.

1.18.10 Crew resource management

The objective of CRM is to reduce human error in aviation. A widely accepted definition of CRM is the effective use of all human, hardware, and information resources available to the

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70 Ibid., p. 24.

71 Flight Safety Foundation, A *Practical Guide for Improving Flight Path Monitoring: Final Report of the Active Pilot Monitoring Working Group* (November 2014), p. 12.

flight crew to ensure safe and efficient flight operations. This goal is accomplished by training flight crews to employ a variety of strategies to help improve effectiveness. CRM skills (i.e., skills to maintain or regain situational awareness, decision making, communication, problem solving, automation management) that are trained recurrently, built into SOPs, and practised frequently, are a known mitigation strategy for unstable approaches.

Interruptions and distractions in the cockpit break the flow pattern of ongoing cockpit activities (actions and communications), such as SOPs, normal checklists, operational communications (listening, processing, and responding), monitoring tasks, and/or problem-solving activities.

The diverted attention resulting from the interruption or distraction usually leaves the flight crew with the feeling of being rushed and being faced with competing or pre-empting tasks. Unless mitigated by adequate techniques designed to help set priorities, this disruption and lapse of attention may result in failure to monitor the flight path; omission of an action and failure to detect and correct the resulting abnormal condition or configuration, if the interruption occurs during a normal checklist, and/or lack of resolution of uncertainties (e.g., regarding an ATC instruction or an abnormal condition).[72]

Another related aspect is maintaining awareness of the unfolding situation. "Situational awareness" is having an accurate understanding of what is happening and what is likely to happen in the future. It involves 3 processes: perception of what is happening, understanding of what has been perceived, and anticipation of what will happen next. Using CRM skills and following company SOPs to build and maintain a common understanding of the situation among the flight crew is another known mitigation strategy for unstable approaches.

1.19 Useful or effective investigation techniques

Not applicable.

72 Airbus Flight Operations Briefing Notes, Human Performance, Human Factors in Incidents/Accidents.

2.0 Analysis

2.1 Introduction

The flight crew was certified and qualified in accordance with existing regulations, and nothing was found to indicate that there was any aircraft failure or system malfunction that contributed to the occurrence before or during the flight. The analysis will focus on explaining how the series of operational and non-operational events encountered by the crew drew their attention away from monitoring and from executing a stable, non-precision approach, and resulted in their lack of awareness of the aircraft's low-energy state just before touchdown. The analysis will also explain the defences that were in place but that were ineffective in preventing an unstable approach from being continued to a landing.

2.2 Flight planning and briefing

Before departure, the flight crew did not notice the Notice to Airmen (NOTAM) explaining that the instrument landing system (ILS) for Runway 07 was not available. As a result, they initially performed an approach briefing for the inoperative ILS approach. Following a call from air traffic control (ATC) enquiring about their selected approach, a second approach briefing for the very high frequency omnidirectional range with associated distance measuring equipment (VOR/DME) Runway 07 approach was conducted. Neither briefing included the aircraft go-around procedure or the specific published missed-approach procedure, which form part of the first approach briefing of the day according to company procedures. In this occurrence, the flight crew was not under any time pressure. It is possible that, given the visual meteorological conditions, a go-around was deemed unlikely, and this may have reduced the perceived importance of the required briefings.

Briefings such as those for approach and for a missed approach are designed to establish a common action plan, to set priorities, and to cue altitudes and other critical information to memory. If flight crews do not conduct thorough briefings, including missed-approach briefings, they may not have a common action plan or set priorities, resulting in reduced crew coordination, which might compromise the safety of flight operations.

2.3 Managing non-operational and operational activities during approach

As the flight proceeded toward the final approach track, the flight crew engaged in non-operational conversation. As a countermeasure against crew distraction, non-operational conversation during critical phases of flight is prohibited by company policy. During this time, the crew also received a call from ATC and reprogrammed the flight management and guidance system (FMGS) for direct flight to the LENAR waypoint.

The Air Canada Rouge standard operating procedures (SOPs) guide flight crews to configure the aircraft at flaps 2 at least 4 nautical miles (nm) prior to reaching the final approach fix (FAF); however, in this occurrence, the aircraft remained configured at flaps 1 until after the aircraft had passed the FAF. Managing the series of operational and non-operational events before the final approach track (i.e., communicating with ATC, reprogramming the FMGS, and carrying out a conversation) may have drawn the flight crew's attention away from appropriately managing airspeed and configuring the aircraft. Also, the aircraft turned onto the final approach track after the LENAR waypoint, which reduced the amount of time the flight crew had to configure the aircraft and manage airspeed.

If flight crews are distracted by other operational and non-operational activities and do not follow SOPs, critical tasks associated with flying the aircraft may be delayed or missed.

2.4 Unstable approach – occurrence flight

2.4.1 Managing the aircraft systems with and without automation

When the aircraft was established on the final approach track, it was at the approximate altitude required for the desired 3.2° approach path. However, because the aircraft was still decelerating, its airspeed was greater than the target airspeed that had been selected. At that point, the aircraft vertical and lateral modes were managed, meaning that the autopilot or flight director systems were directed by the FMGS. When this is the case, the aircraft should follow the vertical and lateral approach path generated by the FMGS, and the autothrust (if in managed mode) should adjust the engine thrust as required.

In this occurrence, however, the autothrust was in a non-managed mode, and the selected speed was 180 knots. As a result, the aircraft was attempting to maintain 180 knots. At this point, the aircraft should have been decelerating to meet the FAF final approach speed (V_{APP}) of 134 knots. If the autothrust had been in a managed mode, the aircraft would have decelerated automatically.

The aircraft did not immediately start to descend, likely because it was moving too fast to descend on the given approach profile from its current location. Subsequently, the crew lowered the landing gear to slow down the aircraft and expedite the descent.

The flight crew then selected a higher target speed on the flight control unit (FCU), increasing it from 180 knots to 190 knots, and finally to 200 knots, likely in an attempt to increase the vertical descent rate. The descent rate increased, reaching 2000 feet per minute (fpm). However, the aircraft also accelerated, reaching 198 knots, when it should have been decelerating. The flight crew's selection of a higher target speed before the FAF resulted in an increased-thrust and high-airspeed condition. This condition contributed to the crew's confusion and misunderstanding of what the aircraft was doing, and resulted in their mismanagement of the configuration sequence.

Shortly afterward (12 seconds later), as a result of flight crew input, the target speed switched from a selected airspeed to a managed airspeed of 134 knots (V_{APP}). As a result, the autothrust reduced the engine thrust, and the airspeed began to decrease.

After deviating above the approach profile, the aircraft crossed the FAF at the appropriate altitude; however, its airspeed (188 knots) was 54 knots faster than V_{APP}, with flaps 1 still selected. Company SOPs state that the aircraft should cross the FAF stabilized at V_{APP}, with flaps 3 selected.

At this point, the pilot flying (PF) selected a flight path angle (FPA) of 3.2° on the FCU, which is the appropriate FPA from the FAF to the runway. The vertical flight mode changed to FPA. These modes were appropriate for the aircraft's position on the approach and were within company and aircraft operating procedures. The autopilot and autothrust were on.

As the aircraft passed the FAF arrival gate, it met all of the stabilized approach criteria in the company policy. The aircraft had regained the approach profile, and its vertical speed was acceptable. The aircraft was tracking appropriately laterally. However, its airspeed was much higher than that specified by the SOPs, and its flaps were set to 1 instead of 3. Therefore, although the stabilized approach criteria were met, the airspeed and flap setting were contrary to the SOPs. If an air operator's SOPs are not consistent with its stable approach policy, there is a risk that flight crews will continue an approach while deviating from the SOPs, resulting in an unstable approach.

According to company SOPs, the landing gear is normally selected down after flaps 2 is selected and before flaps 3 is selected. However, the SOPs permit flight crew to lower the landing gear at any time owing to operational requirements. During the occurrence approach, the landing gear selection was made outside of the normal procedural sequence, before the flaps 2 selection, to increase the deceleration and descent rate in response to the first high-airspeed condition.

The PF requested flaps 3 from the pilot monitoring (PM), bypassing flaps 2. The PF had intended to request flaps 2, but his error was not detected by the PM. The PM moved the flap selector from flaps 1 to flaps 3, although the speed was higher than the maximum allowable for that flap setting. It could not be determined why there was no corresponding call from the PM to ensure that the speed was correct, nor why there was no communication between the flight crew members clarifying the flap settings. During this time, there was also a call from ATC. The PM made 2 further attempts to select flaps 3. On the third attempt, the flaps reached the flaps 3 position.

Shortly afterward, the flight crew pulled the altitude selector (ALT/SEL) knob on the FCU; as a result, the flight modes switched to open climb (OP CLB) and climb thrust (THR CLB). Consequently, there was a sudden and substantial increase in thrust from near idle to 87%. The PF had disengaged the autopilot, so the aircraft did not climb, as commanded by the automation. However, given that the autothrust was still engaged, the airspeed increased a second time, and a flap overspeed alarm sounded.

The increased speed and climb commanded by the automation when the flight crew pulled the ALT/SEL knob were not required during this phase of the approach. Furthermore, when the knob was pulled, the preselected altitude was above the current altitude, which did not correspond to any descent strategy. This further destabilized the aircraft. There are several other knobs and pushbuttons on the FCU and on the adjacent panels in the area of the glareshield. The pulling of the ALT/SEL knob was likely the result of an inadvertent FCU selection; that is, the flight crew had meant to select a different input.

The inadvertent FCU selection resulted in a second high-airspeed and increased-thrust condition. The aircraft deviated above the approach profile between the FAF and the 500-foot arrival gate, and a flaps-3 overspeed alarm sounded. In response, the PF disengaged the autothrust, which he called out to the PM.

2.4.2 *Unstable approach*

The PM initiated the flap-selection check after the PF had disengaged the autothrust and the PM had configured the aircraft with flaps 3. At the "Autothrust" item of the checklist, the check was interrupted by a discussion about the missed-approach altitude and was subsequently not completed. These 2 operational events occurred as the aircraft descended past the 500-foot arrival gate (100 feet above minimums), and a call of "Stable" was not made. The timing of the operational discussion as the aircraft descended past the 500-foot arrival gate may have diverted the attention of the PM from his duties, causing an essential task (a "Stable" call) to be missed. As a result, the flight crew missed an opportunity to recognize an unstable approach.

When the aircraft was on final approach, at 400 feet, the flight warning computer (FWC) annunciated "four hundred." Following the FWC annunciation, the PF made the stable call of "hundred above, stable, minimums." However, the PF made the "Stable" call when the aircraft was not stabilized, as its airspeed was high, the landing checks were incomplete, and the thrust was at idle. As a result, the flight crew continued an unstable approach. The aircraft had returned to the approach vertical profile, which was likely what the PF recognized as stable.

2.4.3 *Energy management*

As previously explained in the report, an aircraft's energy condition is a function of its airspeed (and airspeed trend), altitude, drag, and thrust. In this occurrence, just before the first high-airspeed condition, the flight crew extended the landing gear, thereby increasing drag. However, the airspeed did not decrease; rather, it increased, because the crew selected a higher airspeed on the FCU. The flight crew eventually returned the autothrust to a managed mode; as a result, the target airspeed decreased to V_{APP}, and the aircraft began to decelerate.

The second high-airspeed condition occurred when the PF called for flaps 3 after the aircraft had crossed the FAF. A series of inputs to the FCU by the flight crew then caused the aircraft to increase thrust because of its mode of operation, which resulted in the flight crew misunderstanding what the aircraft was doing. To reduce airspeed and regain control, the PF disengaged all of the automation, including the autothrust.

Management of the aircraft's energy condition diverted the flight crew's attention from monitoring and controlling airspeed during the descent. As a result, the aircraft passed the FAF arrival gate at a high airspeed and with a flaps configuration that was not in accordance with the SOPs.

It is normal practice and standard procedure for flight crews to use autothrust for landing and to maintain thrust above idle to maintain the approach profile and facilitate a missed approach. However, the flight crew's management of the second high-airspeed condition and the interruption of the landing flap check resulted in an autothrust OFF and thrust IDLE condition of which the flight crew was unaware.

The flight crew did not recognize that the airspeed was decaying as the aircraft approached the runway, nor that the autothrust was off. While on short final approach, the airspeed decayed well below V_{APP}, placing the aircraft in an undesired aircraft state at a very low altitude. The PF applied full nose-up side-stick input, and the angle of attack (AOA) reached maximum levels. As a result, during the flare, the aircraft's AOA protection system engaged, reducing the pitch angle. The protection system functioned as designed, and as a result no significant nose-up elevator movement occurred, although full nose-up side-stick input had been applied before touchdown.

The crew were unaware of the low-energy state just before touchdown, as they believed that the autothrust was on. At 50 feet before touchdown, the flight crew suddenly realized that airspeed had been decaying and applied full manual thrust (i.e., maximum take-off thrust); however, in the time remaining before touchdown, the thrust increased by only 4%. When the flight crew recognized the undesired aircraft state, the late addition of engine power was insufficient to arrest the descent rate, resulting in a hard landing.

2.4.4 Monitoring approach stability

This occurrence involved factors that have been shown to increase the likelihood that an unstable approach is continued to a landing. For example, there were no environmental issues, such as wind shear, runway contamination, or instrument meteorological conditions, that would increase the perceived risk of the situation. As a result, the pilots likely anticipated a routine approach and landing. This may have contributed to the crew's acceptance of deviations from the stabilized approach criteria. Until it reached the 500-foot stabilized approach gate, the aircraft was slightly high and fast but regained the profile twice as the flight crew worked to manage the conditions of high airspeed and increased thrust. The actions taken by the crew to reduce the airspeed indicated that they were aware of the high and fast energy state of the aircraft. Past the 500-foot arrival gate, with the autothrust disengaged and the thrust at idle, the aircraft's airspeed continued to decay, resulting in an on-profile and low-energy state by 100 feet above ground level.

A number of situational factors likely contributed to the flight crew not recognizing that the aircraft had shifted from a high-energy state to a low-energy state:

- The flight crew had spent most of the approach working to reduce airspeed while descending and had finally reduced airspeed sufficiently just past the 500-foot arrival gate. They did not anticipate a low-airspeed condition.
- The flight crew was behind schedule in changing flap configurations and in approach-and-landing checks until just past the 500-foot arrival gate. They believed the aircraft to be stabilized at that point.

- Procedures, parameter-deviation calls, and checks were interrupted, delayed, or missed, reducing the flight crew's awareness of actual flight parameters and aircraft system states.
- Monitoring of the overall approach was not maintained as the flight crew focused on resolving the condition of high airspeed and increased thrust.

Air Canada Rouge SOPs require the PM to call out excessive deviations from normal sink rate or from the approach profile in both visual flight rules and instrument flight rules meteorological conditions. In this occurrence, it could not be determined why the PM did not recognize the flight parameters that indicated that the approach was unstable. It is possible that the transition from the PF flying the aircraft with the automation on to flying the aircraft manually, combined with the thrust increases, contributed to a high workload, and that these deviations were therefore not noted by the PM. In addition, because the flight crew regained the approach profile following each airspeed deviation, there were recent cues that the aircraft, which was perceived as stable, was on profile. As a result, the degree of instability, including the shift from a high-airspeed condition to a low-airspeed condition, was not identified, and a go-around was not initiated.

Air Canada Rouge had stabilized approach criteria and policy, a no-fault go-around policy, and a safety management system hazard- and occurrence-reporting policy. Despite these factors, which encourage flight crews to conduct a go-around when an aircraft is not stabilized for approach, the unstable approach was continued. The flight crew did not adhere to the SOPs, which required the monitoring of all available parameters during approach and landing. With both flight crew members focused on the airspeed conditions and aircraft configuration delays, the instability of the approach was not identified and a go-around was not conducted.

Current defences against continuing unstable approaches have proven less than adequate. Unless further action is taken to reduce the incidence of unstable approaches that continue to a landing, the risk of controlled flight into terrain (CFIT) and of approach-and-landing accidents will likely persist.

2.5 Automation

At Air Canada Rouge, it is normal procedure to fly approaches in managed mode. The flight crew's handling of the 2 high-airspeed conditions (i.e., thrust increase before the FAF and the climb thrust increase after the FAF) while attempting to maintain the approach profile demonstrated that the crew misunderstood what the aircraft was doing in its given modes of automation. After a few attempts to reduce airspeed by directing the automated systems, and following the unexpected thrust increase, the PF disengaged all of the automation, including the autothrust, in order to control the aircraft manually. This disengagement is a recommended course of action in such a situation, and the appropriate calls were made.[73]

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[73] Ibid.

Further, the PF's switching to manual control resulted in the aircraft slowing down and regaining the approach profile near the 500-foot arrival gate. However, the PF did not remember that the autothrust was disengaged and that thrust was at idle as the aircraft continued to landing.

2.6 Crew resource management and standard operating procedures

As part of the normal discharge of their operational duties, flight crews employ countermeasures to prevent threats, errors, and undesired aircraft states from reducing safety margins during flight operations. Examples of such countermeasures include checklists, checks, briefings, calls, and SOPs, as well as crew resource management (CRM) skills (i.e., decision making, automation management, communication, and maintenance of situational awareness and attention). In this occurrence, throughout the approach to landing, critical elements of communication between the flight crew, including checks, calls, and cross-checks of excessive flight parameter deviations and flight mode annunciator (FMA) mode changes, were delayed or missed altogether.

Humans are inclined to focus attention on responding to problems or abnormal situations, even when the issues involved are benign in nature. CRM skills and SOPs, and regular training in them, are designed as a countermeasure against flight crews focussing on threats and errors rather than on flying the aircraft or managing an undesired aircraft state. If flight crews do not adhere to standard procedures and best practices that facilitate the monitoring of stabilized approach criteria and excessive parameter deviations, there is a risk that threats, errors, and undesired aircraft states will be mismanaged.

2.7 Flight crew training

Air Canada Rouge has a stabilized approach criteria and policy. However, at the time of the occurrence, Air Canada Rouge did not provide flight crews with simulator training in recognizing an unstable approach leading to a missed approach. As a result, the occurrence flight crew did not recognize the multiple deviations in airspeed and thrust or the deficiencies in coordination and communication, and they continued the approach well beyond the stabilization gates. Training scenarios that involve go-arounds following an unstable approach may increase the likelihood that pilots will carry them out during active flight operations.

At the time of the occurrence, Air Canada Rouge did not include autothrust-off approach scenarios in each recurrent simulator training module, nor are they required to do so by regulation. The flight crews routinely fly with the automation on. As a result, the occurrence flight crew was not fully proficient in autothrust-off approaches, including management of the automation.

According to the *Commercial Air Service Standards* (CASS), air operators are required to provide flight crew members with training in all types of instrument approaches, using all levels of automation. At the time of the occurrence, Air Canada Rouge was providing training for autothrust-off approaches during initial training, but not during recurrent training. However, there is no specification in the CASS regarding the frequency of such training or how it is to be conducted, only that all items for the initial training syllabus must be covered over a defined period of time (through a cycle).

If standards for flight crew training in relation to automation proficiency (CASS 725.124) are not explicit with regard to frequency, there is a risk that air operators will exclude critical elements from recurrent training modules and that flight crews might not be proficient in all levels of automation.

3.0 Findings

3.1 Findings as to causes and contributing factors

2. The flight crew's selection of a higher target speed before the final approach fix resulted in an increased-thrust and high-airspeed condition. This condition contributed to the crew's confusion and misunderstanding of what the aircraft was doing, and resulted in their mismanagement of the configuration sequence.

3. The inadvertent flight control unit selection resulted in a second high-airspeed and increased-thrust condition. The aircraft deviated above the approach profile between the final approach fix and the 500-foot arrival gate, and a flaps-3 overspeed alarm sounded. In response, the pilot flying disengaged the autothrust.

4. The timing of the operational discussion as the aircraft descended past the 500-foot arrival gate may have diverted the attention of the pilot monitoring from his duties, causing an essential task (a "Stable" call) to be missed. As a result, the flight crew missed an opportunity to recognize an unstable approach.

5. The pilot flying made the "Stable" call when the aircraft was not stabilized, as its airspeed was high, the landing checks were incomplete, and the thrust was at idle. As a result, the flight crew continued an unstable approach.

6. Management of the aircraft's energy condition diverted the flight crew's attention from monitoring and controlling airspeed during the descent. As a result, the aircraft passed the final approach fix arrival gate at a high airspeed and with a flaps configuration that was not in accordance with the standard operating procedures.

7. While on short final approach, the airspeed decayed well below final approach speed (V_{APP}), placing the aircraft in an undesired aircraft state at a very low altitude.

8. When the flight crew recognized the undesired aircraft state, the late addition of engine power was insufficient to arrest the descent rate, resulting in a hard landing.

9. The flight crew did not adhere to the standard operating procedures, which required the monitoring of all available parameters during approach and landing. With both flight crew members focused on the airspeed conditions and aircraft configuration delays, the instability of the approach was not identified and a go-around was not conducted.

10. Air Canada Rouge did not provide flight crews with simulator training in recognizing an unstable approach leading to a missed approach. As a result, the occurrence flight crew did not recognize the multiple deviations in airspeed and thrust or the deficiencies in coordination and communication, and they continued the approach well beyond the stabilization gates.

11. Air Canada Rouge did not include autothrust-off approach scenarios in each recurrent simulator training module, and flight crews routinely fly with the automation on. As a result, the occurrence flight crew was not fully proficient in autothrust-off approaches, including management of the automation.

3.2 *Findings as to risk*

1. If flight crews do not conduct thorough briefings, including missed-approach briefings, they may not have a common action plan or set priorities, resulting in reduced crew coordination, which might compromise the safety of flight operations.

2. If flight crews are distracted by other operational and non-operational activities and do not follow standard operating procedures, critical tasks associated with flying the aircraft may be delayed or missed.

3. If flight crews do not adhere to standard procedures and best practices that facilitate the monitoring of stabilized approach criteria and excessive parameter deviations, there is a risk that threats, errors, and undesired aircraft states will be mismanaged.

4. If an air operator's standard operating procedures (SOP) are not consistent with its stable approach policy, there is a risk that flight crews will continue an approach while deviating from the SOPs, resulting in an unstable approach.

5. If standards for flight crew training in relation to automation proficiency (*Commercial Air Service Standards* 725.124) are not explicit with regard to frequency, there is a risk that air operators will exclude critical elements from recurrent training modules and that flight crews might not be proficient in all levels of automation.

4.0 *Safety action*

4.1 *Safety action taken*

Air Canada Rouge conducted an internal safety management system (SMS) investigation into this occurrence and an assessment of its flight operations. In the course of the investigation, the company identified and took steps to mitigate the risks associated with portions of its flight operations, specifically unstable approaches. Air Canada Rouge has taken the following corrective actions:

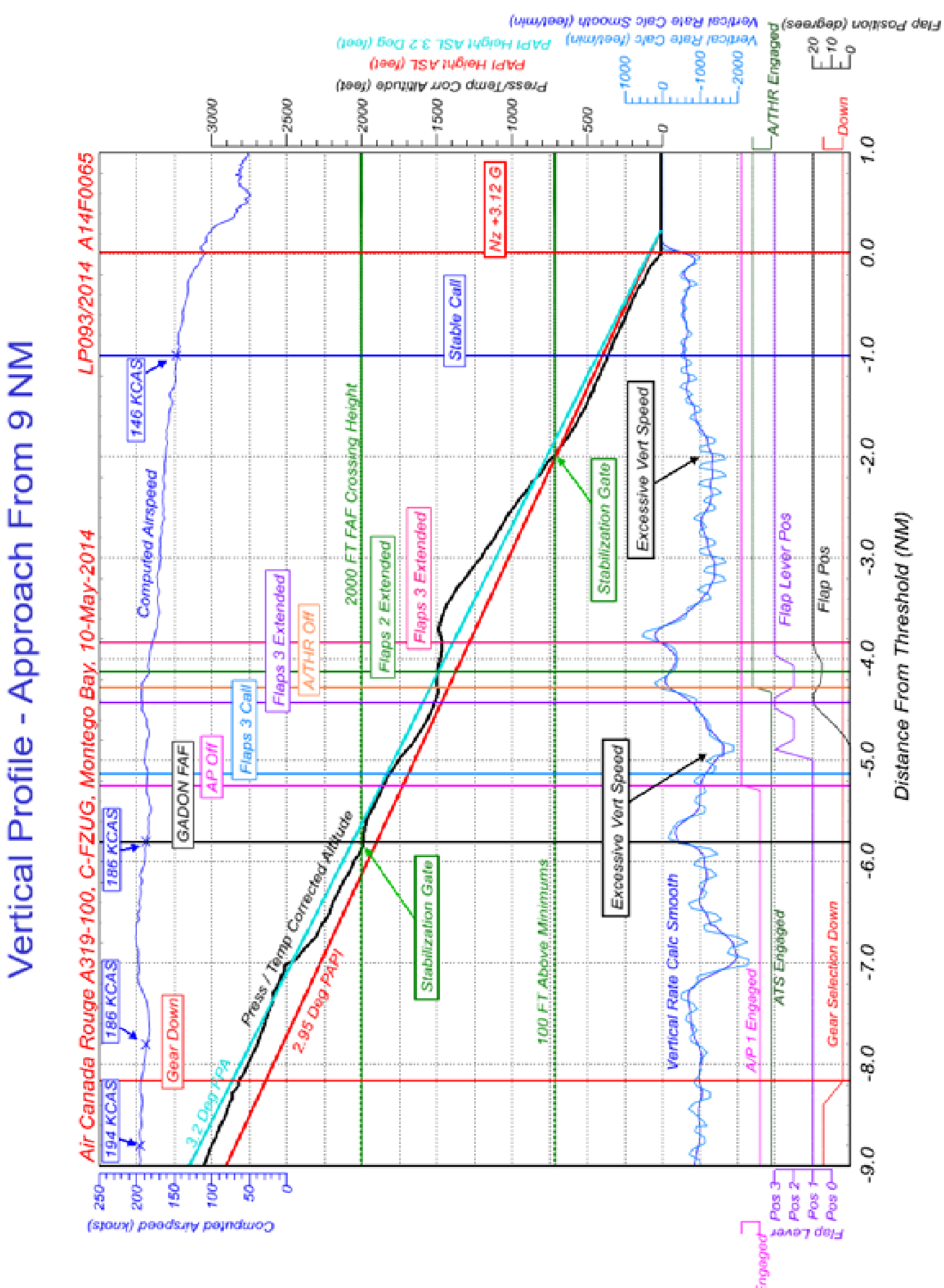
- It has incorporated simulator training for unstable approaches leading to a go-around into the syllabus for recurrent training of flight crew. The intent is to incorporate the same training into the initial type training, but this action has not been completed yet.
- It has modified the recurrent training syllabus to include more manual flying, including controlled flight into terrain (CFIT) recovery, steep turns, approach to stall, upset recovery, autothrust disconnection and reconnection, and operations with autothrust off.
- It has implemented standard operating procedure (SOP) changes, which refined the company's stable approach policy. The changes were developed based on consultation with Air Canada, the findings of the company's internal investigation on this occurrence, and the latest proposals from the Flight Safety Foundation.
- It has improved the annual recurrent training program, including new and/or improved modules on dealing with distractions on the flight deck; leadership and professional standards, focusing on open communication; and dealing with non-compliance with standard operating procedures by the other flight crew member.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 13 October 2016. It was officially released on 09 January 2017.

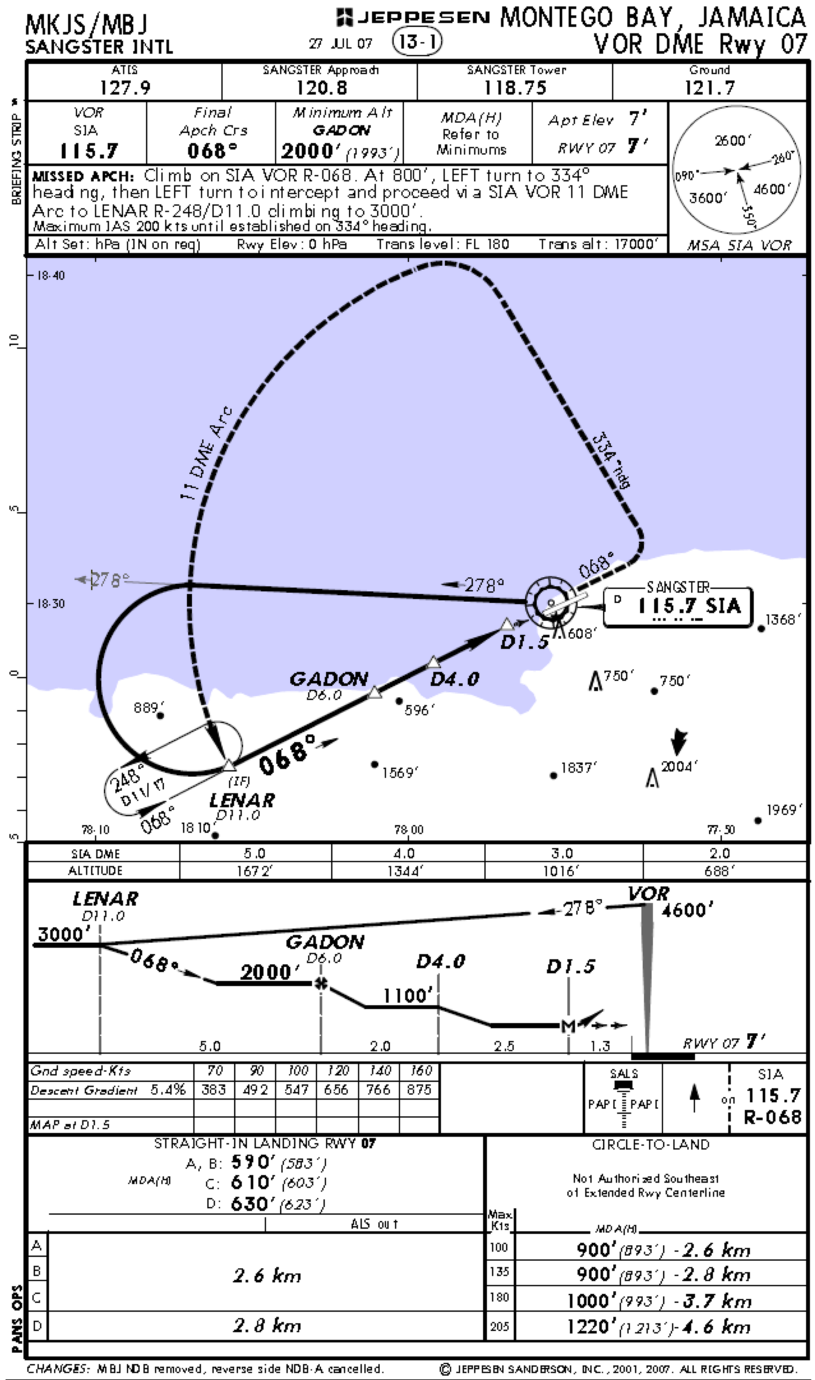
Visit the Transportation Safety Board's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken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

Appendices

Appendix A – Aircraft vertical profile



Appendix B – VOR DME Runway 07 approach, Sangster International Airport (MKJS)



Source: Jeppesen Sanderson, Inc., 2001, 2007

Appendix C – Deviations from standard operating procedures

Item	Air Canada Rouge standard operating procedures	Actual occurrence events
At 4 nm before final approach fix (FAF)	[*Pilot flying*] (PF)... "FLAPS 2" [*Pilot monitoring*] (PM)... "SPEED CHECKED" Ensure the current indicated airspeed (IAS) does not exceed the limit for Flap 2 extension. PM... "FLAPS 2...F SPEED" Check deceleration toward the F Speed. If in Selected Speed ensure that the speed is appropriate and the PF is cognizant of the selection, e.g., "FLAPS 2...170 SELECTED".	• Flaps 2 not called (flaps 1 down) • Speed not checked • Aircraft not decelerating
At 3 nm before FAF	PF... "GEAR DOWN" The PF may request the gear be extended at any time in order to aid the descent for the approach. It is procedurally selected prior to calling for the Landing Check. PF... "LANDING CHECK" The landing check normally accompanies the gear down call. However, if the landing gear is needed earlier to aid in descent and/or deceleration the call "GEAR DOWN" should be made. The call "LANDING CHECK" will then be delayed until established on Final [*approach*].	• Gear selected down • Landing check not called
At 2 nm before FAF	PF... "FLAPS 3" PM... "SPEED CHECKED" • Ensure the current IAS does not exceed the limit for Flap 3 extension. If CONF 3 (flaps 3) landing is planned: PM... "FLAPS 3...V_{APP} 139"	• Flaps 1 down • Flaps 3 called 0.7 nm after FAF • Airspeed exceeded flaps 3 setting • Final approach speed (V_{APP}) not called
At the FAF passage	The PM will make the final calls as per the [*Flight Operations Manual*] FOM (below): At the FAF the PM calls the passing altitude and crosschecks it against the charted FAF crossing altitude, corrected for temperature as required, and the PF confirms the called altitude is within 100 feet on the barometric altimeter. The PM checks appropriate missed approach altitude is set in the altitude selector. The [*Aircraft Operating Manual*] AOM SOPs managed non-precision approach diagram indicates: V_{APP} stable and landing configuration (flap 3 or full) at FAF.	• No calls at the FAF • Airspeed 188 knots (not decreasing) • Not in landing configuration • V_{APP} not stable • Appropriate missed-approach altitude not set
Landing flap selection	The PF will call for landing flap (Config[*uration*] 3 or Full). The PM will select and confirm the required flap, then make the standard call e.g., "Flap Full … V_{APP} 134", followed by:	• V_{APP} not called • Autothrust called by PM, but not actioned by PF; landing checklist not

	– PM.................................. "AUTOTHRUST" – PF.................................. "SPEED", or "OFF" – PM.................................. "LANDING MEMO",........ "NO BLUE" – PF.................................. "NO BLUE" Once the final landing flap call is complete the PM calls "AUTOTHRUST" then, following the PF response, ensures no blue annunciations remain on the [*electronic centralized aircraft monitor*] ECAM LANDING MEMO and calls "LANDING MEMO, NO BLUE". The PF confirms no blue annunciations on the ECAM Landing MEMO, and calls "NO BLUE".	completed
At decision altitude/decision height/minimum descent altitude plus 100 feet	Calls by the PF and PM are made as per FOM policy. PM............. "HUNDRED ABOVE, STABLE or (UNSTABILIZED)", PF.................................. "ROGER", or "GO-AROUND, FLAPS" V_{APP} stable (+10, –5) knots from V_{APP} The "Unstabilized" call may be made at any time on approach if conditions warrant. At any time during the approach if it becomes apparent that the Stable Approach Criteria will not be met or maintained, a go-around shall be initiated.	PF called "Hundred above, stable" at wrong altitude Speed 160 knots (V_{APP} + 26) No stable/unstabilized call Aircraft unstable due to airspeed, thrust idle, no landing checklist

Appendix D – Glossary

AAE	above airport elevation
agl	above ground level
ALAR	approach-and-landing accident reduction
ALT/SEL	altitude selector
AOA	angle of attack
AOM	Aircraft Operating Manual
asl	above sea level
ASR	air safety reports
ATC	air traffic control
A/THR	autothrust activated
CARs	Canadian Aviation Regulations
CASA	Civil Aviation Safety Alert
CFIT	controlled flight into terrain
CRM	crew resource management
CVR	cockpit voice recorder
ECAM	electronic centralized aircraft monitor
FAF	final approach fix
FCU	flight control unit
FDM	flight data monitoring
FDR	flight data recorder
FL	flight level
FMA	flight mode annunciator
FMGS	flight management and guidance system
FOM	Flight Operations Manual
FPA	flight path angle
fpm	feet per minute
FSF	Flight Safety Foundation
FWC	flight warning computer
HGS	heads-up guidance system
ILS	instrument landing system
IMC	instrument meteorological conditions

METAR	aviation routine weather report
NOTAM	Notice to Airmen
OP CLB	open climb
PAPI	precision approach path indicator
PF	pilot flying
PFD	primary flight display
PM	pilot monitoring
RNAV	area navigation
SMS	safety management system
SOPs	standard operating procedures
TC	Transport Canada
THR CLB	climb thrust
TOGA	takeoff/go-around
TRK	track
TSB	Transportation Safety Board
V_{APP}	final approach speed
VASIS	visual approach slope indicator
VMC	visual meteorological conditions
VOR/DME	very-high-frequency omnidirectional range with associated distance measuring equipment
VS	vertical speed