Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

# AVIATION INVESTIGATION REPORT
# A07O0124

# HARD LANDING AND MAIN LANDING GEAR COLLAPSE

## AIR CANADA JAZZ
## BOMBARDIER REGIONAL JET CL-600-2B19, C-FRIL
## TORONTO, ONTARIO
## 20 MAY 2007

Canada

# Aviation Investigation Report

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## Bombardier Regional Jet CL-600-2B19, C-FRIL
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## *Summary*

The Air Canada Jazz Bombardier CL-600-2B19 Regional Jet (registration C-FRIL, serial number 7051), with 3 crew members and 37 passengers on board, was operating as Air Canada Jazz Flight 8911 from Moncton, New Brunswick, to Toronto/Lester B. Pearson International Airport, Ontario. At 1235 eastern daylight time, the aircraft landed on Runway 06R with a 90° crosswind from the left, gusting from 13 to 23 knots. The aircraft first contacted the runway in a left-wing-down sideslip. The left main landing gear struck the runway first and the aircraft sustained a sharp lateral side load before bouncing. Once airborne again, the flight and ground spoilers deployed and the aircraft landed hard. Both main landing gear trunnion fittings failed and the landing gear collapsed. The aircraft remained upright, supported by the landing gear struts and wheels. The aircraft slid down the runway and exited via a taxiway, where the passengers deplaned. There was no fire. There were no injuries to the crew; some passengers reported minor injuries as a result of the hard landing.

# *Other Factual Information*

The enroute portion of the flight from Moncton to Toronto was uneventful. The first officer was the pilot flying (PF). The pilots were aware that a crosswind landing would be required and that the winds had been reported as gusty. The pilots completed the required pre-landing checklists. Approaching Toronto, the pilots had good visual contact with the ground.

For the landing on Runway 06R, Air Canada Jazz 8911 would overfly the departure end of Runway 24L, where an Airbus A340 (Air France 358) had come to rest after overrunning Runway 24L in August 2005 [1]. Air Canada Jazz requires a sterile cockpit below 10 000 feet above aerodrome elevation [2]. During the approach, the captain made a number of non-operational comments and approximately four minutes prior to touchdown, when the aircraft was 10 nautical miles (nm) from the runway at 3000 feet above sea level (asl), he brought out his personal camera to take a series of pictures of the A340 accident site. During the approach, the captain's attention was divided between taking pictures and monitoring the approach and landing.

The aircraft was on autopilot throughout the approach. There were no warnings or alerts recorded on the digital flight data recorder (DFDR) and engine parameters were normal. While on autopilot, the aircraft was flying a stabilized approach. When the aircraft was 0.4 nm from the threshold at 700 feet asl (170 feet above runway elevation), the captain put away his camera.

The Air Canada Jazz standard operating procedures (SOPs) required the autopilot to be disengaged on approach at a minimum of 80 feet above ground level (agl) and for this action to be called out by the PF. Thrust levers are to be reduced to idle at 50 feet agl; this is to allow the engine speed (N1) [3] to spool down to idle thrust before the touchdown. On the accident flight, the autopilot was disengaged at between 30 and 40 feet agl. The flare was initiated at about 30 feet agl. At about 5 feet agl, the thrust levers were retarded to approximately 55 per cent. Idle N1 is 25 per cent in standard atmospheric conditions.

The aircraft contacted the runway about four seconds after the autopilot was disengaged. After this initial ground contact, the aircraft bounced to a height of about 10 feet agl and then descended to land with significant force.

During the first runway contact, the aircraft was on a heading of 051 degrees; the runway heading is 057 degrees. The aircraft was in a left-wing-down sideslip, and the left main landing gear touched down first. The aircraft then rolled rapidly to the right, the nose swung to the right, and the right main landing gear touched down. The nose wheel did not touch down.

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1 TSB Report A05H0002 – Airbus A340 Overrun of Runway 24L, Toronto/Lester B. Pearson International Airport

2 The sterile cockpit rule prohibits crew members from performing non-essential duties or other activities while the aircraft is at a critical stage of flight (Rhona Flin, Paul O'Connor, Margaret Crichton, *Safety at the Sharp End*, Ashgate Publishing, 2008, page 33).

3 N1 – The engine fan rotor speed

The initial ground contact lasted approximately ½ second; during that time, the aircraft experienced a lateral load of approximately 0.3 G and a vertical load of 1.4 G. The DFDR did not record any weight on wheels (WOW) signals; this can be attributed to the brevity of the ground contact compared to the DFDR sampling rate or to the condition of the main landing gear struts. There was sufficient ground contact to achieve main landing gear wheel spin-up.

Neither the Bombardier *Flight Crew Operating Manual* (FCOM) nor the aircraft operating manual (AOM) specifically provide a bounced landing recovery procedure or technique. For the CRJ series aircraft, the rejected/balked landing procedure is described in the Abnormal and Emergency Procedures section of the FCOM. Air Canada Jazz has reorganized this information in its own AOM. At the time of the accident, both documents indicated that commencing a go-around or rejected/balked landing with the aircraft in a low-energy landing regime was a high-risk, undemonstrated manoeuvre. After the aircraft bounced, the captain decided to continue the landing with the first officer flying.

CRJ series aircraft are equipped with a ground lift dump (GLD) system that is used to assist in aircraft braking and to minimize bounced landings. When specific deploy logic is met at touchdown, the aircraft is determined to be on the ground and the GLD system activates all of the spoilers (spoilerons, flight spoilers, and ground spoilers). Each set of spoilers has its own logic criteria, but all three sets of spoilers require both primary and secondary conditions to be met for deployment. The primary condition requires both thrust levers to be at idle or both engines' N1 to be less than 40 per cent.

In addition to the primary condition, the flight and ground spoilers require one of the following secondary conditions before they will deploy:

- Main gear weight on wheels and radio altitude < 5 feet agl; or
- Main gear weight on wheels and wheel speed >16 knots; or
- Radio altitude < 5 feet agl and wheel speed > 16 knots.

In addition to the primary condition, the spoilerons require one of the following conditions to be met for deployment:

- Main gear weight on wheel and radio altitude < 5 feet agl; or
- Main gear weight on wheels and wheel speed > 16 knots.

When any of the secondary conditions are met, they are latched [4] for four seconds. This time lapse is not unusual; other major manufacturers apply the same logic. In this case, Bombardier applies four seconds to compensate for fluctuations in the sampling rate of the radar altimeter.

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[4] "Latched" is an engineering term used by Bombardier to describe the condition where the GLD system's secondary parameters are essentially locked or on standby, waiting for the primary condition – thrust levers to idle – to be met.

For this landing, the GLD system did not activate during the first touchdown because the thrust levers were not retracted to idle and the N1 remained at approximately 55 per cent. However, the condition of radio altitude < 5 feet agl and wheel speed > 16 knots was latched for 4 seconds. After the bounce, at a height of between eight and ten feet agl, the deploy logic was met when the thrust levers were fully retarded to idle. At that point, the flight and ground spoilers deployed. The spoilerons did not because the main gear weight on wheels condition was not satisfied during the first touchdown.

When the GLD system devices activated, the loss of lift caused the aircraft to descend very rapidly. It hit the runway at a sink rate of about 20 feet per second. The certification standard is 10 feet per second. The subsequent impact detached both main landing gear struts from the wing and both main landing gear folded. The main landing gear trunnion fitting failures occurred within 0.25 seconds of each other.

The aircraft is designed so that if there is a gear collapse on landing, the gear will fold rearward in such a way that it will not puncture the fuel tank. This design functioned as intended and, because both landing gear collapsed, the aircraft continued the landing rollout by sliding straight down the runway with the wings level. To the flight crew, the aircraft appeared to respond normally to steering and engine power inputs.

The captain steered the aircraft onto high-speed taxiway Delta 3, where it came to a stop. The pilots did not recognize that the aircraft was at a different deck angle and were not aware that the main landing gear had collapsed; nor did the flight attendant, who was seated at the front of the passenger cabin. After stopping, the pilots assessed that there might be damage from the hard landing and concluded that they probably had flat tires.

Some passengers were seated where they could hear loud scraping noises as the aircraft slid down the runway, and they could see that the wingtips were much closer to the ground than they normally would be. A small number of oxygen masks deployed during the landing. This resulted in an odour of burning from the heat build-up in the associated passenger oxygen generators. The passengers remained calm and the flight attendant made an announcement as to the source of the odour.

Numerous aural warnings and fault signals activated in the cockpit, many of which could not be silenced or de-activated. The pilots had difficulty initiating a call to the tower to report their status because of steady communication involving other aircraft. About 1 ½ minutes after touchdown, the pilots reported that they had a flat tire and requested that equipment be sent. Crews of other aircraft had noticed the damage to the aircraft and had reported that there was debris on the runway.

About two minutes after the aircraft stopped, the flight attendant initiated contact with the cockpit to see when they would be moving to the gate. The captain advised they would be parked for a minute. The flight attendant reported that there were a couple of oxygen masks down and a couple of bins had opened. Three minutes after the landing, the captain made an announcement telling the passengers to remain seated and that they would be taxiing shortly.

At the captain's request, the first officer contacted company maintenance and reported a hard landing and a flat tire. The captain initiated engine shutdown about four minutes after the landing. The captain assessed that there was no need to immediately deplane the passengers after confirmation from the flight attendant that the passenger cabin was secure and that there appeared to be no injuries. The captain requested that a bus be brought to the aircraft to transport the passengers.

After the aircraft was shut down, the captain exited the aircraft through the passenger door to check the condition of the aircraft. Upon observing the damage, the captain immediately ordered a rapid disembarkation and that the passengers be moved upwind of the aircraft.

Several passengers made their way toward the doorway when the passenger door was initially opened. Having the passengers in the doorway blocked the flight attendant from access to the megaphone. It was stored in bin 1AC on the opposite side of the flight attendant position and passenger exit door. The remainder of the flight attendant's emergency equipment was stored closer to the flight attendant position, and therefore more readily accessible.

Without access to the megaphone, the flight attendant raised her voice and instructed the passengers to deplane and to leave all personal items behind. Several passengers took personal items with them. Once the passengers were off the aircraft, the flight attendant did a final check of the cabin and washrooms and then did a head count on the taxiway to ensure that everyone was out of the aircraft.

Both pilots were certified and qualified for the flight in accordance with existing regulations. The captain had a total flying time of 12 700 hours, with 1500 hours on CRJ series aircraft, and had been a captain on CRJ series aircraft since 2005. The first officer had a total flying time of 4000 hours, had been flying with this airline for less than two months, and had about 100 hours on CRJ series aircraft. His previous experience was on single and light twin propeller aircraft, including time as captain on Beechcraft 1900 series aircraft.

In the previous three days, the captain had flown 7 hours and the first officer flew 8 hours. On the day of the accident, both pilots had 8 hours or more of sleep. They both reported for work at 0700 and they had flown together from Toronto to Moncton and back, a total of 4 hours.

This was the first pairing for this flight crew. There were no formal procedures in place to ensure that captains were aware of the aircraft-specific experience level of the first officers assigned to the flights, nor were such formal procedures required by regulation. The captain was aware that the first officer was relatively new to the company.

Ground school, simulator and flight training for the first officer included briefings on the crosswind landing technique, multiple simulated crosswind landings, and at least one landing at the maximum demonstrated crosswind of 27 knots. His training also included rejected/balked landings. This training stressed that if a pilot had any doubt about making a safe landing he should initiate a go-around or rejected landing prior to the aircraft entering a low-energy landing regime. The Air Canada Jazz AOM stated that commencing a go-around while in the low-energy landing regime is a high-risk undemonstrated manoeuvre.

Bounced landings had not been part of either the captain's or the first officer's training. The Bounced landing technique was introduced by Bombardier in the 15 June 2007 pilot reference manual.

There is no regulatory requirement for pilots to be trained on bounced landing procedures. In a report released on an accident that occurred on 09 May 2004 in Puerto Rico [5], the United States (US) National Transportation Safety Board (NTSB) made the following recommendation: "Require all 14 Code of Federal Regulations Part 121 and 135 air carriers to incorporate bounced landing recovery techniques in their flight manuals and to teach these techniques during initial and recurrent training." On 09 June 2006, referencing this occurrence, the US Federal Aviation Administration (FAA) issued Safety Alert for Operators (SAFO) 06005 to certificate holders operating under Title 14 of the Code of Federal Regulations (14 CFR) parts 121 and 135. The stated purpose of the SAFO was to emphasize the importance of operators ensuring that they have procedures and training for bounced landing recovery.

Shortly after the SAFO was issued, Bombardier updated the CRJ FCOM with the following:

> CRJ Supplementary Procedures – Bounced Landing Procedure:
>
> The GLD system is very effective in preventing bounced landings on the CRJ series aircraft. Its automatic deployment requires that the thrust levers be at IDLE prior to touchdown, as they should be for all landings on the CRJ.
> If the pilot believes that thrust must be added and maintained until touchdown to salvage a landing, then a balked/rejected landing should be executed.
> Should the aircraft bounce on landing, a balked/rejected landing should be executed. Go-around thrust should be set and the normal landing attitude or slightly higher should be maintained. Aircraft configuration should not be changed at this time. Once the aircraft is accelerating above VREF and climbing through a safe height, the go-around manoeuvre should be continued.
> Improper landing technique (thrust levers not at IDLE) may result in a shallow bounce. Should the pilot decide not to execute a balked/rejected landing, then the normal landing attitude should be maintained and the thrust levers reduced to IDLE. Be aware that following the bounce, the GLD may deploy as soon as the thrust levers are set to IDLE, even if the aircraft is still in the air.
> A poorly executed approach and touchdown with a high rate of descent can generate a high, hard bounce that can quickly develop into a hard landing accident. A balked/rejected landing should always be executed following such a bounce.

Starting in January 2007, Air Canada Jazz incorporated bounced landing recovery training into its recurrent simulator training, modeled after the Bombardier bounced landing procedure. The training was to be completed by 30 June 2007. The captain on the accident flight was scheduled for this training on 26 May 2007, six days after the accident flight. As the first officer had not received bounced landing procedure training during his initial checkout, neither of the pilots on the accident flight had received bounced landing training on the CRJ series aircraft.

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[5] Report number NTSB/AAR-05/02 - a bounced landing accident involving an Avions de Transport Regional (ATR) 72-212

The following is a summary of company SOPs relevant to this occurrence:

- The flight crew is to maintain a sterile cockpit during the descent and approach phases of flight below 10 000 feet. Two requirements for a sterile cockpit are: operational conversation only and essential operational activities only.

- Standard, mandatory call-outs are to be made by the pilot not flying.

- Autopilot must be disengaged at an altitude no lower than 80 feet agl.

- For a crosswind landing, maintain runway alignment by crabbing into the wind and, when commencing the flare, gently apply rudder to align the aircraft with the runway centreline. Apply aileron to prevent a sideways drift. There is a note to not exceed 10 degrees of bank.

On the day prior to the occurrence, another flight crew noted that the accident aircraft was sitting right wing low. Maintenance found that the shock strut on the right main landing gear was low. There was no evidence of fluid leakage, so the strut was serviced by adding nitrogen to bring it to the proper extension. As the aircraft began to taxi away, the strut extended so that the right wing was now high. The shock strut was then serviced following the recommended procedures in the maintenance manual. This included releasing nitrogen from the strut, topping it back up again, and taxiing the aircraft to ensure that the strut remained at its proper extension. After this procedure, the aircraft was returned to service and had completed five uneventful flights before the occurrence.

Information about the above maintenance activities was entered into the aircraft's journey log book; however, the flight crew did not take note of these log book entries because the maintenance release had been completed and the aircraft was returned to service.

Maintenance history of the landing gear shows that the landing gear had been overhauled in 2002. At that time the shock struts should have been dismantled, inspected, and re-serviced before being re-installed on the aircraft. None of the subsequent maintenance on the landing gear involved disassembly of the shock struts.

Following the occurrence, both of the main landing shock struts were examined by the manufacturer (Messier-Dowty). The following anomalies were noted:

Left main gear shock strut:

- Shock strut nitrogen pressure – unable to measure due to valve damage from the accident.

- Pressure under compression was 1184 psi – recommended value 2230 to 2440 psi.

- Quantity of hydraulic fluid was 1450 ml – recommended quantity is 1658 ml.

- Fluid extremely dirty, resembling piston engine oil.

Right main gear shock strut:

- Shock strut nitrogen pressure was 951 psi - 427 psi above the recommended pressure (524 psi plus or minus 10 psi).
- Pressure under compression was 1132 psi – recommended value 2230 to 2440 psi.
- Quantity of hydraulic fluid was 1250 ml - the recommended quantity is 1658 ml.
- Fluid extremely dirty, resembling piston engine oil.

The above anomalies were present during the accident flight. The landing gear manufacturer was asked to conduct a theoretical analysis to determine if these anomalies would contribute to a bounce. It concluded that the lack of fluid would reduce the energy dissipating capacity of the shock strut due to the lack of damping, possibly contributing to the tendency to bounce.

The failed landing gear trunnion fittings were examined at the TSB Engineering Laboratory to determine the cause of the structural failure. The examination concluded that the material was consistent with that specified by the manufacturer. There were no metallurgical flaws or defects. The mode of failure was overload. There was no indication of pre-existing fatigue.

Following the accident, the maintenance facility examined two sets of shock struts that had gone through the same overhaul procedure in 2002 as the accident set. In particular, they examined the set that had gone through the overhaul procedure immediately prior to the accident set and the ones that had gone through it immediately after. Both sets were found to be serviceable. The circumstance that led to the non-airworthy condition of the accident shock struts was not determined. It was assessed as an anomaly and no further action was taken.

# *Analysis*

The wind conditions for the landing were within the capabilities of the aircraft. For an airline flight crew, the landing conditions were not abnormal.

The first officer, who was significantly less experienced on this aircraft type than the captain, was the pilot flying. He had limited experience with crosswind landings in the CRJ series aircraft, and the gusty wind was sufficient to add complexity to the landing. When the captain engaged in non-operational activity during the final part of the approach, it left the first officer with nearly all of the decision making and control of the aircraft.

The captain did not notice that the first officer left the autopilot engaged to well below the stipulated minimum altitude. In leaving the autopilot engaged, the first officer reduced the normal amount of time to get a hands-on feel for the aircraft as it approached the runway. As a result, the first officer was not able to align the aircraft's heading with the runway or eliminate the excessive sideslip during the flare.

The first officer was also very late reducing the thrust levers to idle, again with no intervention by the captain. The thrust levers were not completely reduced for the initial touchdown. This not only eliminated the bounce protection normally provided by the GLD system, but also made the aircraft lighter on its wheels and more susceptible to bouncing.

Neither the aircraft operating manual nor the training that both pilots had received mentioned the importance of conducting a balked or rejected landing when the aircraft bounces. This information was incorporated after the accident. Thus, when the aircraft bounced, given the low energy state, the first officer likely attempted to salvage the landing rather than execute the balked landing procedure. In the attempt to salvage the landing, the thrust levers were retarded all the way to idle. This was the final parameter for the GLD system to initiate spoiler activation. Had either pilot advanced the thrust levers, the GLD logic would have resulted in the spoilers retracting.

The anomalies found in the shock struts, including the condition of the hydraulic fluid, indicate that the struts were processed through the overhaul facility in 2002 without being adequately serviced. The quality control in place at the time did not detect this irregularity and these non-airworthy shock struts were installed on the aircraft. Subsequent maintenance on the landing gear did not involve inspection of the pressurized sections of the shock struts, so the struts remained in a non-airworthy condition. Although the aircraft had completed a number of successful landings with these shock struts installed and there were no reported adverse bounce tendencies, the shock struts would not be absorbing the normal amount of energy on touchdown and would have contributed to the bounce on this landing.

The following TSB Engineering Laboratory reports were completed:

LP 047/2007 – Flight Data Recorder (FDR)/Cockpit Voice Recorder (CVR) Analysis

LP 085/2007 – Hydraulic Fluid Analysis

LP 058/2007 – Main Landing Gear Bracket Failure

These reports are available from the Transportation Safety Board of Canada upon request.

## *Findings as to Causes and Contributing Factors*

1. On final approach, the captain diverted his attention from monitoring the flight, leaving most of the decision making and control of the aircraft to the first officer, who was significantly less experienced on the aircraft type. As a result, the first officer was not fully supervised during the late stages of the approach.

2. The first officer did not adhere to the Air Canada Jazz standard operating procedures (SOPs) in the handling of the autopilot and thrust levers on short final, which left the aircraft highly susceptible to a bounce, and without the bounce protection normally provided by the ground lift dump (GLD) system.

3. Neither the aircraft operating manual nor the training that both pilots had received mentioned the importance of conducting a balked or rejected landing when the aircraft bounces. Given the low-energy state of the aircraft at the time of the bounce, the first officer attempted to salvage the landing.

4. When the thrust levers were reduced to idle after the bounce, the GLD system activated. The resultant sink rate after the GLD system deployed was beyond the certification standard for the landing gear and resulted in the landing gear trunnion fitting failures.

5. There was insufficient quality control at the landing gear overhaul facility, which allowed non-airworthy equipment to enter into service. The condition of the shock struts would have contributed to the bounce.

## *Findings as to Risk*

1. Several passengers took carry-on items with them as they exited the aircraft, despite being instructed not to do so.

2. The location of the stored megaphone did not allow the flight attendant to have ready access after the passengers started moving to the exit door.

## *Safety Action Taken*

On 26 September 2006, Air Canada Jazz sent an e-mail to all of its simulator and line training instructors to raise awareness about the dangers of landing the CRJ series aircraft with residual thrust, reminding them that it could contribute to a bounced landing. This information was officially incorporated into the 01 October 2007 update of its line indoctrination guide, which provides guidance on administering line training.

*This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 02 June 2009.*

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