CIAIAC

COMISIÓN DE INVESTIGACIÓN DE ACCIDENTES E INCIDENTES DE AVIACIÓN CIVIL

Report A-003/2007

Landing in gear-up configuration involving a Bombardier CL 600-2B19, registration EC-IBM, operated by Air Nostrum, at Barcelona Airport, on 24 January 2007

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Edita: Centro de Publicaciones
Secretaría General Técnica
Ministerio de Fomento ©

NIPO: 161-10-060-1
Depósito legal: M. 23.129-2003
Imprime: Diseño Gráfico AM2000

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Foreword

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the event and its causes and consequences.

In accordance with the provisions of Law 21/2003 and pursuant to Annex 13 of the International Civil Aviation Convention, the investigation is of exclusively a technical nature, and its objective is not the assignment of blame or liability. The investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than preventing future accidents.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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Abbreviations

.DAT	Computer file extension
.FDT	Computer file extension
.WAV	Computer file extension
00°	Degrees
00 °C	Degrees centigrade
AD	Airworthiness Directive
AFM	Aircraft Flight Manual
AIP	Aeronautical Information Publication
APP	Approach control
ATC	Air Traffic Control
ATIS	Airport Traffic Information Service
ATPL(A)	Airline transport pilot
BC	Board Concern (TSB Canada publication)
BPSU	Brake and Position Sensor Unit
CDL	Configuration Deviation List
CIAIAC	Civil Aviation Accident and Incident Investigation Commission (Spain)
cm	Centimeter(s)
CPL(A)	Commercial Pilot
CRJ	Canadair Regional Jet
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
DFDR	Digital Flight Data Recorder
DME	Distance Measuring Equipment
EGPWS	Enhanced ground proximity warning system
EFIS	Electronic Flight Instrumentation System
EICAS	Engine Indication And Crew Alerting System
FAA	Federal Aviation Administration
FAF	Final approach fix
FECU	Flaps electronic control unit
FIM	Fault Isolation Manual
FLAP FAIL	EICAS flap failure warning
ft	Feet
ft/min	Feet/minute
g	Gravity acceleration
GPWS	Ground Proximity Warning System
GS	Ground speed
h	Hour(s)
hPa	Hectopascals
IAS	Indicated airspeed
ILS	Instrument landing system
ILS-CAT III	Category-3 ILS
km	Kilometer(s)
kt	Knot(s)
m	Meter(s)
MTOW	Maximum takeoff weight
NM	Nautical miles
OPS	Operations (organization within operator or ATS services)
P/N	Part number
PAPI	Precision Approach Path Indicator
PDU	Power drive unit for flaps
PF	Pilot flying
PNF	Pilot not flying
PRM	Air Nostrum Pilots Reference Manual
QNH	Altimeter setting to obtain altitude above sea level
QRH	Quick Reference Handbook
RA	Radio altitude

Abbreviations

RCA	Reglamento de Circulación Aérea (Air Traffic Regulations)
RWY	Runway
S/N	Serial number
SAIB	Special airworthiness information bulletin
SEI	Servicio de extinción de incendios (Fire extinguishing services)
TAT	Total air temperature
TDZ	Touchdown zone
TEM	Threat and error management
THRS	Runway threshold
TSB	Transportation safety bureau
TWR	Control tower
UTC	Coordinated universal time
VOR	VHF omnidirectional range

Synopsis

Owner and operator:	Air Nostrum
Aircraft:	Bombardier CL 600-2B19, registration EC-IBM
Date and time of accident:	24 January 2007; 14:06 h (UTC)
Place of accident:	Runway 25R at Barcelona airport.
Persons onboard and injuries:	Pilot, copilot, 2 cabin crew and 40 passengers. Two passengers slightly injured
Type of flight:	Commercial Air Transport – Domestic – Passenger
Date of approval:	21 December 2009

Event summary

The aircraft was preparing to land in a zero-flaps configuration due to a failure in the extension system. During the landing, upon making contact with the runway, it became obvious that the landing gear had not deployed. The aircraft slid on its belly until it came to a stop on the runway, where the passengers were evacuated. There were no injuries onboard except for two persons, who suffered slight bruises during the evacuation.

The investigation revealed that the omission to actuate the landing gear extension lever, before touchdown, was the direct cause of the accident; consequently, a belly landing in a gear-up configuration followed. A contributing factor was the presence of certain technical anomalies in the operation of the flaps system which attracted the attention of the crew.

The report includes four (4) safety recommendations. Additionally, the manufacturer and the aviation authority of Canada, State of design of the aircraft, have adopted measures intended to prevent future anomalies in the operation of the flaps system on aircraft of this type.

1. FACTUAL INFORMATION

1.1. History of the flight

On 24 January 2007, the Bombardier CL 600-2B19, registration EC-IBM, was on a scheduled passenger flight operated by Air Nostrum, with call sign ANS-8665, from Valladolid to Barcelona. Onboard the aircraft were 40 passengers and a crew of 4: pilot, copilot and two cabin crew. The captain was the pilot flying.

It was the crew's first flight of the day and the aircraft's fourth. On the two previous flights, there had been problems with extending the flaps before landing, first in Paris and then in Valladolid, where the aircraft had to land with the flaps retracted.

During the ground tests performed by the crew in Valladolid, the flaps extended and retracted normally, and so the captain decided to continue with the flights as scheduled.

During the flight, the crew went over the abnormal procedures to be followed in case of a repeat failure of the flaps system.

After taking off from Valladolid, the flaps were retracted normally and remained retracted during the cruise and descent phases until the initial approach to Barcelona, at which time they failed to extend to the 8-degree position when commanded, resulting in a «flap fail» warning on the EICAS (Engine Indication and Crew Alerting System) in the cockpit. The copilot noted the discrepancy between the commanded 8° position on the flaps lever and the 0° indicated position. At that time they were below the clouds and under ATC radar control.

In the zero-flaps configuration, the ILS approach speed, in accordance with the relevant procedure, had to be maintained above 180 kt. ATC cleared them for the runway 25R approach and informed of a moderate intensity crosswind of 14 kt from 320°.

The aircraft descended until it touched down at an IAS of 172 kt, at which time the crew realized they had not lowered the landing gear. After a long slide on the runway, the aircraft stopped within the runway and 240 m from its end.

No general fires were reported, though high temperatures and kerosene leaks were detected. A firefighting vehicle that was on the tarmac immediately reported to the scene, and sprayed the part of the aircraft in contact with the ground with fire retardant foam. The aircraft, which was stranded in the middle of the runway, was evacuated using the two front doors 1L and 1R, and door 2R atop the right wing. The emergency window on the left side was not opened.

Two passengers were slightly bruised during the evacuation. The remaining occupants were not injured.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatal				
Serious				
Minor		2	2	Not applicable
None	4	38	42	Not applicable
TOTAL	4	40	44	

1.3. Damage to aircraft

The aircraft was seriously damaged by the abrasion of the lower fuselage surface with the asphalt surface of the runway.

1.4. Other damage

Five lights embedded in the runway 25R touchdown zone were damaged due to friction with the fuselage.

1.5. Personnel information

The crew consisted of two flight crew and two cabin crew.

The flight crew was on its first flight of the day. It had taken charge of the aircraft during the stopover in Valladolid, relieving the crew that had flown the previous legs to Paris and then from Paris to Valladolid.

1.5.1. *Captain*

Age:	45
Sex:	Male
Nationality:	Spanish
License:	ATPL (A)
Total flying hours:	5,102 h
Flying hours on the type:	2,969 h

Seniority as captain:	October 06
Flying hours as Capt:	202:02 h
Last refresher course:	October 06
Rest prior to flight:	14:55 h
Flight activity in last 24 h:	07:50 h
Flight activity in last 5 days:	37:20 h

The pilot had held a type rating for the ATR-72, acting as copilot and with an experience of 890 flying hours.

His first flight on the CRJ-200 was in April 2003 as a copilot, after having received his type rating. In October 2006 he successfully completed the pilot in command course for this type of aircraft and was certified as pilot in command. He did his in-flight training and line training under supervision and was finally certified as a CRJ-200 captain on 24 November 2006. He failed an advancement course for pilot in command of the ATR-72 aircraft in June 2005.

1.5.2. *Copilot*

Age:	29
Sex:	Female
Nationality:	Spanish
License:	CPL(A)
Total flying hours:	2,000 h (approximately)
Flying hours on the type:	200 h
Last refresher course:	September 2006
Rest prior to flight:	14:55 h
Flight activity in last 24 h:	07:50 h
Flight activity in last 5 days:	37:20 h

The pilot took the copilot type rating course for the ATR-72/500 aircraft in June 2003, received her type rating as copilot and was line certified for flight in October 2003. In August 2006 she took the type rating course for the CRJ-200 aircraft, did her in-flight training and line training under supervision and on November, same year, was certified as a CRJ-200 copilot.

1.6. Aircraft information

1.6.1. *General*

The Bombardier CL-600-2B19 aircraft, also called CRJ-200, is a twin-engine jet airplane with a capacity for 50 passengers and intended for use as a regional, short-range aircraft.

The company Air Nostrum operates 35 units of this type on its domestic and inter-regional flights with neighboring European countries.

It has a conventional tricycle gear with two twin wheels on each leg. The main gear legs retract under the fuselage and wings by rotating on two hinges aligned with the airplane axis. The nose gear leg folds forward and is housed in the nose wheel well.

The wings have high-lift trailing edge surfaces, or flaps, and no high-lift leading edge devices, or slats. The EFIS instrumentation features six cathode ray displays, two of which show the EICAS (Engine Indication and Crew Alerting System) information.

The forward fuselage has two doors, the one on the left being normally used for embarking passengers, and the one on the right being a service door. Both door frames are at a height of 1.61 m above the ground when the aircraft is on the ground with its landing gear deployed. The passenger door itself doubles as the access stairs by opening downward. A third door for baggage is located on the aft left side of the fuselage. Two windows in the central fuselage, one on each side, can be used as emergency exits.

1.6.2. *Frame*

Manufacturer:	BOMBARDIER
Model:	CL-600-2B19 «CRJ-200»
Manuf. Number:	7591
Year of manufacture:	2001
Registration:	EC-IBM
MTOW:	23.133 kg
Owner:	AIR NOSTRUM
Operator:	AIR NOSTRUM

1.6.3. *Airworthiness certificate*

Number:	5038
Class:	Normal

Issue date:	11 Dec 2004
Expiration date:	09 Feb 2007

1.6.4. *Maintenance log*

Total flying hours:	14,643 h
Total cycles:	11,776 h
Last C inspection (4,000 h):	19 Nov 2005 with 11,410 h
Last A1 inspection (500 h):	07 Aug 2006 with 13,386 h
Last A2 inspection:	05 Oct 2006 with 13,852 h
Last A3 inspection:	01 Dec 2006 with 14,298 h
Last A4 inspection:	07 Jun 2006 with 12,883 h
Engines replaced:	18 May 2006 with 12,713 aircraft hours

The day before the accident the aircraft overnighted in Barcelona. The aircraft was dispatched for its first flight of the day with three deferred maintenance items which were unrelated with the flaps or fault warning systems. No new faults were annotated in the flight logs at the conclusion of the three flights preceding the accident flight.

1.6.5. *Engines*

Manufacturer:	General Electric
Model:	CF-34-3B1
Serial numbers:	GE-E873222 and GE-E873224

1.6.6. *Loadsheet*

A load and balance sheet was drafted for the dispatch of the aircraft in Valladolid specifying the following data for the flight:

Actual landing weight: 19,850 kg	Max landing weight: 21,200 kg
Actual takeoff weight: 21,050 kg	Max takeoff weight: 23,133 kg

Takeoff fuel:	2,600 kg
Trip fuel:	1,200 kg

Number of passengers onboard: 40

1.6.7. *Flaps*

The aircraft's high-lift device consists of two articulated flap surfaces placed in the trailing edge of each wing which must be used during normal operations in the landing and takeoff phases. In case of a system failure, there is no alternative procedure for extending the flaps, and the landing must be executed with the flaps in their existing configuration. If the flaps are stuck at 0°, the landing speeds can be high and are limited by the tires, whose maximum design speed is 182 kt.

The flaps are extended and retracted by means of eight spindle actuators, two per panel, actuated by flexible shafts which transmit the rotation of two electric motors, the PDUs (Power Drive Units). One FECU (Flaps Electronic Control Unit) tracks the successive flaps positions through the BPSU (Brake and Position Sensor Unit) and controls the PDUs. If the flaps are asymmetrically extended, or if they are stuck or seized, there is a skew detection system which, through the FECU, stops the PDUs and actuates the brakes to block the surfaces from any further movement, locking them in the position reached when the problem first appeared.

A lever in the cockpit is used to select the desired flaps position during operations. Associated with the flaps is an indication of the actual position of the surfaces, which can be seen on the EICAS screen both digitally and graphically.

When a FECU fault occurs, or when the flaps are operating asymmetrically, a "FLAP FAIL" warning appears on the first page of the EICAS.

So as to assist with maintenance tasks, the FECU internal memory records all fault events with a code for the type of fault, the affected components and the possible causes leading to the fault.

The scheduled maintenance log for the flaps system was as follows:

Lubrication and visual inspection of internal and external actuators on both sides (500 h)	On 07 Jun 2006 with 12,883 aircraft hours, on 07 Aug 2006 with 13,386 h, on 05 Oct 2006 with 13,851 h and on 01 Dec 2006 with 14,298 h.
Operational test of the skew detection system and functional test (500 h)	On 05 Oct 2006 with 13,851 aircraft hours and 01 Dec 2006 with 14,298 h.
Detailed inspection of the internals of the flexible transmission shaft on both sides (1,000 h)	On 30 Mar 2006 with 12,387 aircraft hours, on 07 Aug 2006 with 13,386 h and on 01 Dec 2006 with 14,298 h.
Detailed inspection of the externals of the flexible transmission shaft on both sides (1,000 h)	On 07 Jun 2006 with 12,883 aircraft hours and on 05 Oct 2006 with 13,851 h.

1.6.8. *EGPWS*

The CRJ-200 features a system to warn of the dangers entailed by flying at low altitudes so as to avoid colliding with the terrain, the EGPWS (Enhanced Ground Proximity

Warning System). Its Mode 4, Unsafe terrain clearance, which is subdivided into Modes 4A and 4B, provides specific warnings based on aircraft configuration, specifically the landing gear and the position of the flaps. The modes that could have been of relevance to this flight are described below.

- Mode 4A. Active during cruise and approach phases when the flaps and gear are not in a landing configuration and the speed is below a set speed as determined by the altitude (190 kt at 1,000 ft AGL or a lower speed at 500 ft). If these limit conditions are reached, a flashing 'GND PROX' warning illuminates and an aural 'TOO LOW, GEAR' alert is heard. If the speed is above 190 kt, the aural warning is 'TOO LOW TERRAIN' and the 'GND PROX' warning remains lit.
- Mode 4B. Active during cruise and approach phases when the gear is down but the flaps are not in a landing configuration. The boundary for activation of Mode 4B starts at a radio altitude of 245 ft and increases linearly with speed, up to a maximum of 1,000 ft RA. If the boundary is crossed at less than 159 kt, a flashing 'GND PROX' light turns on and an aural 'TOO LOW, FLAP' signal is heard. The crew can cancel the aural warning by pressing the 'FLAP OVRD' button on the EGPWS panel. If the boundary is crossed at a speed in excess of 159 kt, the aural warning is 'TOO LOW, TERRAIN' and the 'GND PROX' warning remains lit.

1.6.9. *Landing gear warnings*

The landing gear has an air/ground sensing subsystem which informs the airplane of its status, whether it is resting on the ground or airborne, and to detect whether the landing gear legs are retracted or extended.

The position of each landing gear leg is shown on the first page of the EICAS screen:

- UP
- DN
- (yellow), leg in transition
- (flashing yellow), position unknown
- (red), the leg in question is not locked

In flight, starting two minutes after takeoff, a landing gear warning horn will sound if various conditions are met; in particular, if the gear is not down with all three legs locked if either of the two throttle levers is placed in the idle position and if the speed is below 185 kt with the flaps positioned at less than 5 degrees, the horn will sound continuously. The horn can be silenced by pressing a button on the gear lever, but it cannot be silenced if both throttle levers are placed at idle. The gear not locked alarm horn also sounds when the down and locked signal is not received at a radio altitude below 1,000 ft and the descent rate is above 400 ft/min. The amber light for one or more legs will flash on the EICAS display.

1.6.10. *Aircraft performance*

The minimum landing distance required by the airplane (actual landing distance-ALD) under conditions of 0-degree flaps, normal sea level pressure and a (estimated landing) weight of 19,850 kg is 1,439 m. The landing distance required and therefore available at an airfield (landing distance available-LDA) should be the 167% from this one, it means 2,400 m. The runway length used by the aircraft during its landing was 3,100 m.

The approach speed for 0° flaps and 20,000 kg weight is 167 kt.

The maximum tire speed is 182 kt.

1.6.11. *Minimum equipment list*

The MEL specifies that with a flap fault shown on the EICAS screen, the flight cannot be initiated.

With other partial faults in the subsystems (FECU channels, skew detection system, flaps position potentiometers, and the flaps PDU motors), the aircraft can fly under certain conditions specified in the MEL.

1.7. Meteorological information

The aircraft's own data recorders reveal that the temperature for the departure in Valladolid was 5 °C.

The departure weather information provided by ATC was: runway in use, 23, wind 320/11 kt, CAVOK, temperature 4 °C, dew point –5 °C, and QNH 1,015 hPa.

According to ATIS information in Barcelona, the wind in the touchdown zone of runway 25R was from 310° at 14 kt. The temperature was 10 °C, with few clouds at 3,500 ft and scattered clouds at 9,000 ft.

The average temperature at cruising altitude was 35 degrees below zero.

1.8. Aids to navigation

The electronic aids to navigation available to the accident aircraft on approach to runway 25R were: ILS CAT-III and VOR/DME, which were working correctly.

Under radar control the aircraft was vectored from the entrance to the control area, right downwind, and on base and final within a pattern of five aircraft that were on approach to Barcelona at that time. The radar traces confirm that flight ANS-8665 intercepted the localizer 8 NM out from the threshold of runway 25R on a normal approach path.

1.9. Communications

The aircraft was in radio contact at all times with approach control and tower control. A transcript of the recordings of these communications was available and generally matched the information recorded on the CVR.

The transcripts of the communications revealed a cluster of transmissions in the two minutes and a half that the radio contact with TWR lasted. In that interval, some 36 transmissions were made between TWR and the five airplanes tuned to its frequency.

1.10. Aerodrome information

The aerodrome of Barcelona-El Prat is at an elevation of 12 ft and it has two parallel runways, 07L-25R and 07R-25L, normally used for the takeoff and landing operations of aircraft. Another third runway, 02-20, crosses both of the others.

The runway used by the accident aircraft, ANS-8665, was 25R, which is 3,352 m long and 60 m wide. The elevation at the threshold is 10 ft. The runway surface has a convex profile with a slight upward slope for the first 250 m, a zero slope for 2,175 m in its central part, and a slight downward slope over the last 250 m.

Runway 25R has a PAPI visual aid for the approach glide slope and an ILS. Both the PAPI visual slope and the ILS CAT III glide slope have a 3° slope.

There are no obstacles in the runway 25R approach area and, being virtually at sea level, barometric altitudes should coincide with radio altitudes (RA). Likewise, flight altitudes and airplane altitudes should be the same for aircraft on approach.

Appendices 3 and 4 shows the AIP-Spain Instrument Approach Plate for runway 25R and the Aerodrome Chart.

1.11. Flight recorders

1.11.1. *Cockpit Voice Recorder, CVR*

The aircraft was equipped with a solid state L3 Communications CVR, with a 120-minute recording capacity, P/N S200-0012-00 and S/N: 000147189.

This recorder was taken from the airplane and sent to the laboratories of Canada’s Transport Safety Board (TSB), where it was read. Four WAV files were obtained from it, corresponding to the area microphone, communications with the passengers, and to the pilot and copilot seats. The communications corresponding to the crew's seats were not clear because the microphones on the headsets were not located near the sound source, meaning that neither crew member was wearing the headsets.

The 120-minute recording period encompasses the entire flight, and even the arrival of the previous flight and the stopover period during which the system was on.

The recorded conversations reveal that:

- The captain of the previous flight informed company operations that the aircraft had a problem with the flaps and that he was unsure whether the next flight could proceed.
- During the turnover, the captain being relieved informs the oncoming captain that the flaps had failed on two occasions. On departing from Paris he was warned that the same thing would probably happen again in Valladolid due to the cold, though he suspects that they may operate properly on the ground. He says that he has contacted the company, Operations and Maintenance, and that they are aware of the problem.
- The flaps were successfully extended and the oncoming captain assumed charge of the airplane, asking the offgoing captain not to note the anomaly in the flight log as he was taking the airplane to Barcelona where maintenance facilities were available.
- Other comments regarding airplane performance were made, such as the full load speed of 180 kt but not to exceed 182 kt, which is the maximum tire speed. They noted that on short runways, such as Bologna or Pamplona, for example, it would be impossible to land without flaps.
- The company coordinator at Valladolid surmised that the airplane had had problems the day before.
- The captain and copilot held a briefing on the takeoff maneuver and informed the cabin crew. They authorized boarding. They decided that the pilot flying would be the captain.
- The captain told the copilot that he had landed before without flaps. The copilot has done so on the simulator.
- Before takeoff and while cruising, they went over the maneuvers, the speeds for the various flaps positions, and the procedures as per the QRH (Quick Reference Handbook). They anticipated that the airplane would glide quite a lot during the flare at 180 kt before landing, but trusted the length of the runway at Barcelona would be long enough.
- The flight proceeded normally and some 25 minutes before arrival, radio contact was established with ATC Barcelona, which informed them that runway 25R was in use.
- They listened to the ATIS information; in particular, wind 310°/14 kt and visibility greater than 10 km.
- At 14:00:30, after passing below 3,500 fr, at 190 kt, they select 8° flaps but the flaps did not extend. The 'FLAP FAIL' caution message appeared. They informed ATC-APP of the fault, and that as a consequence they would maintain a speed above 170 kt during the approach.

- They contacted Control-TWR, which was aware of the situation, and were informed of the 3352-m length available to them for the landing.
- Control-TWR also relayed that preceding traffic had warned of the presence of windshear, detected by its instruments.
- In an exchange between the PF and PNF, before 14:04:00, two minutes before landing, the PF said, “Then everything is done, right?”
- The performance of the before landing checklist could not be heard on the recordings.
- ATC asked flight ANS-8665 if they required any assistance, to which they replied no, that everything was fine. TWR cleared them for landing at 14:04:36.
- Several EGPWS warnings then sounded

  TOO LOW - MINIMUMS
  TOO LOW, GEAR
  TOO LOW, TERRAIN
  SINK RATE
  GEAR DISAGREE

  The ‘TOO LOW, GEAR’ warning was repeated 15 times.
- The gear not locked or lowered horn was heard starting two minutes before touchdown, at first intermittently and then continuously for a minute.
- The airplane was heard skidding for 40 seconds on the recording.
- At 14:06:01, flight ANS-8665 informed ATC that it had an emergency.

1.11.2. *Digital flight data recorder, DFDR*

The aircraft was equipped with an L3 COMMUNICATIONS digital flight data recorder, P/N: S800-2000-00, and S/N: 000147154, with a 64 word-per-second data recording speed. It was taken from the aircraft and sent to the operator’s facilities. The raw data were obtained in a compressed format with an FDT extension, and in an uncompressed DAT format, and subsequently processed and transformed into engineering physics units under the supervision of the CIAIAC.

The information examined revealed the following salient points:

- The flight from Valladolid to Barcelona lasted approximately one hour, with the cruise phase lasting 25 minutes.
- The aircraft was cruising at an altitude of 30,000 ft. The Total Air Temperature (TAT) was –35 °C.
- A 175-kt GS, 180-kt IAS, was maintained throughout the approach with a descent rate of 1,000 ft/min.
- The flare was initiated at a 6° pitch up angle. The angle decreased in a few seconds, with the aircraft ending up practically level during the landing run.
- The airplane was oriented at a 4° angle to the right of the runway centerline on final approach, which was reduced to just one degree as the belly of the fuselage touched

down on the runway. During the deceleration run, as the aircraft came to a full stop, the aircraft progressively turned to the right, into the wind, until it was oriented at a 14° angle to the runway in its final stopping position.

- The flare was very smooth. The maximum vertical acceleration at touchdown was 1.16 g, at which time the speed was 172 kt IAS, 168 kt GS.
- Twelve seconds after the maximum vertical acceleration was reached on touchdown, the 'GEAR DISAGREE' warning came on and remained lit for 28 seconds.
- Forty seconds after the instant of maximum acceleration, the GS decreased to zero.
- The distance resulting from an integration of the GS over the final 40 seconds following the instant of maximum vertical acceleration was 1,825 m.
- The integration of the speed over the 14 seconds prior to the instant of maximum vertical acceleration returned a value for the distance covered of 1,270 m. At t = –14s, the RA of the aircraft was 50 ft. The total landing run, therefore, was 3,095 m.
- From t = 41, the data recorded correspond to the period when the aircraft was being recovered and its systems being re-energized.

1.12. Wreckage and impact information

1.12.1. *Marks*

The first abrasion marks from the belly of the airplane on the surface of runway 25R were found 8 m to the left of centerline, past the point where the runway crosses runway 02/20, near high-speed taxiway B-A. The tracks continued all the way to the final stopping point over the left side stripe near runway V3. The aircraft slid on the runway a distance of some 1,900 m.

Figure 1. Aircraft state after the event

The distance from the runway 25R threshold to the first abrasion mark was 1,200 m.

The distance from the final stopping point to the end of the runway 7L threshold was 250 m.

1.12.2. *Condition of aircraft; damage found*

The aircraft frame maintained its integrity. Abrasion damage was noted on the belly and on the main gear doors and on the fairings of the flap actuators on the wings.

It was noted that the main gear legs were closed and that the flap surfaces were not deflected.

The aircraft slid on the runway resting atop the central wing box and the lower wing-fuselage fairings. There was impact damage to the rear fuselage structure affecting the skin, stringers and frames. Friction with the runway produced additional damage to the fairings, actuator spindles and to the flaps hinge boxes on both the left and right wings.

When the aircraft was lifted up on slings, the landing gear was released and the three legs lowered. They were guided into a locked position and the aircraft's weight rested on them. There were no anomalies detected while extending or locking the legs in the down position. Once the airplane was hoisted it was noted that the outboard tires on both main legs had been damaged. They were deflated and their brakes locked, which

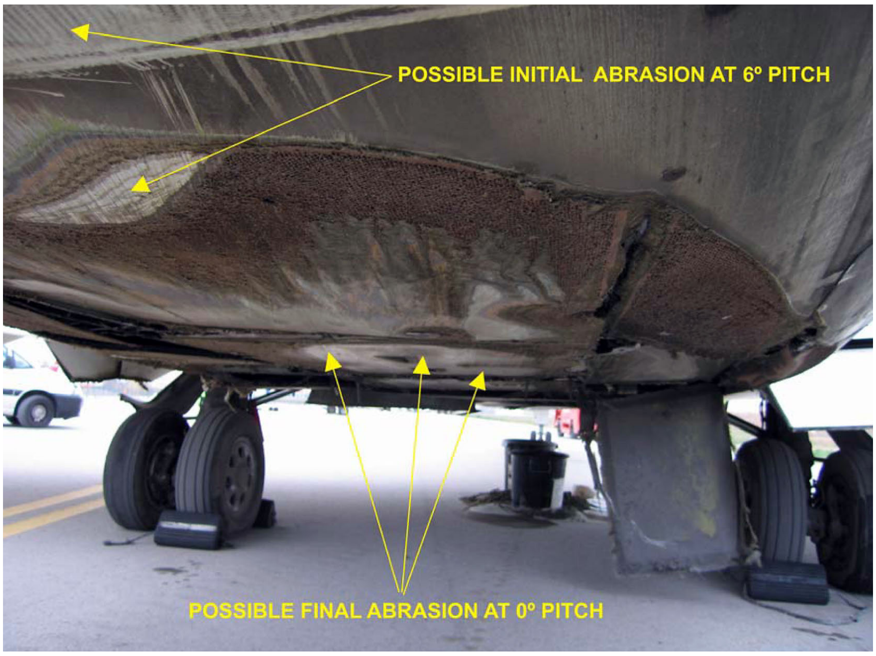


Figure 2. Abrasion marks, scrapes and distortions, on the aircraft belly

posed difficulties when removing the aircraft. The belly fuel tank was perforated and there was a fuel leak. The inboard flap section on the left wing was hanging loose due to damage inflicted to its rails.

Passenger exit doors 1L, right hand door 1R and emergency exit 2R, used for evacuation, were found open. On getting into the main passenger cabin, no damage was observed.

In the cockpit, at the time the aircraft was energized, it was noted that, during the previous flight, a 'FLAP FAIL' message had been recorded in the EICAS. Inmediatelly afterwads, flap surfaces got in motion and adopted the 8° degrees position that was selected in the flap selector lever.

1.12.3. *Positions of controls in the cockpit*

The following cockpit controls were found to be in disagreement with aircraft systems:

- Gear lever lowered (gear retracted and the front leg doors in plain view closed)
- Flaps gear in 8° position (flaps on both sides in retracted position, 0°).

Other controls were found in the following conditions:

- Emergency gear extension lever in its normal position (not used).
- Antiskid in armed position.
- Emergency engines cutoff levers activated, thrust levers in the shut off position and fire push button switched.
- Reversers armed.
- All hydraulic pumps ON.
- Landing lights OFF.
- Emergency lights ON.

1.13. Medical and pathological information

Not applicable.

1.14. Fire

There were no apparent fires. An inspection of the pressurized cabin floor and adjacent structures through the right wheel well revealed the presence of burn marks and high temperatures affecting structural components caused by burning sealant, hydraulic liquids and electrical wiring. A hydraulic liquid container was deformed by burning and melting.

1.15. Survival aspects

Since no generalized fires or structural deformation affected the aircraft, and given the gradual deceleration over 40 seconds, there were no great threats to the physical integrity of the occupants. During the evacuation, facilitated by the normal position of the airplane and by a very low fuselage height with respect to the ground, two passengers received slight bruises due to the speed of the disembarking operation, which had been unannounced since the crew was unaware of the gear-up conditions under which the landing was being conducted.

1.16. Tests and research

1.16.1. *Inspection and disassembly of flaps system components*

The components from the FECU, PDU (2), spindle actuators (8) and flexible shaft segments (10) were sent to the laboratory. In addition to the secondary damage to the actuators caused by the skid down the runway, the inspection disclosed the abnormalities and conditions of the examined components described as follows:

Flexible shafts

- During the inspection of the flap transmission in the right wing, there were clear signs of water mixed with grease on every shaft segment. The presence of water was very evident in segment no. 4, where the grease was dripping.
- During the inspection of the left wing, traces of water were only observed in segment no. 1.
- The amount of grease could be considered normal on all the shafts, the amount being considerably less on those of the left wing, though both were within the manufacturer's recommendations, which calls for a fine layer of grease.
- All the seals on the shaft ends were correctly installed and were in good conditions, except for the outboard end of the no. 3 right shaft (next to the no. 3 actuator), which, though situated in its housing, was abraded.
- All the shafts were inspected and found in good condition. All passed the leak test recommended by Bombardier in its SL 27-089. No leaks were detected.

Figure 3. Flexible drive shaft of flap

FECU

The self-diagnostic internal memory on the FECU was analyzed. The codes recorded involving the fault on the last flight referred to the probable initial cause as a "seizure", as well as to a second and possible third failure cause involving the BPSU components on the right side and the PDU.

The fault itself resulted from the difference between the flaps position selected in the cockpit and the actual position, this due to a progressive seizing of the mechanism's transmission on the right side.

From among the 25 memory slots assigned for this purpose in the FECU memory, there were 25 faults recorded, corresponding to 14 previous flights in which the system had detected seizing of the flexible shafts and of the PDUs, among them the faults that had appeared on the two previous flights.

1.16.2. *History of flaps system malfunctions on aircraft EC-IBM*

The AIR NOSTRUM maintenance records indicate that in the first two weeks of May 2002, there were nine (9) 'FLAP FAIL' incidents and two landings without flaps. After these malfunctions, another fifteen (15) cases of flaps faults were noted for that frame until the eve of the day of this accident. On 9 January 2007, a 'FLAP FAIL' was logged and fixed after cleaning, greasing and checking for proper operation. Ten days later the anomaly was repeated and listed as corrected after checking the operation on the ground. After a new entry of the same fault the day before the accident, the system was noted as operative after cleaning the actuator spindles and checking the operation of the flaps several times.

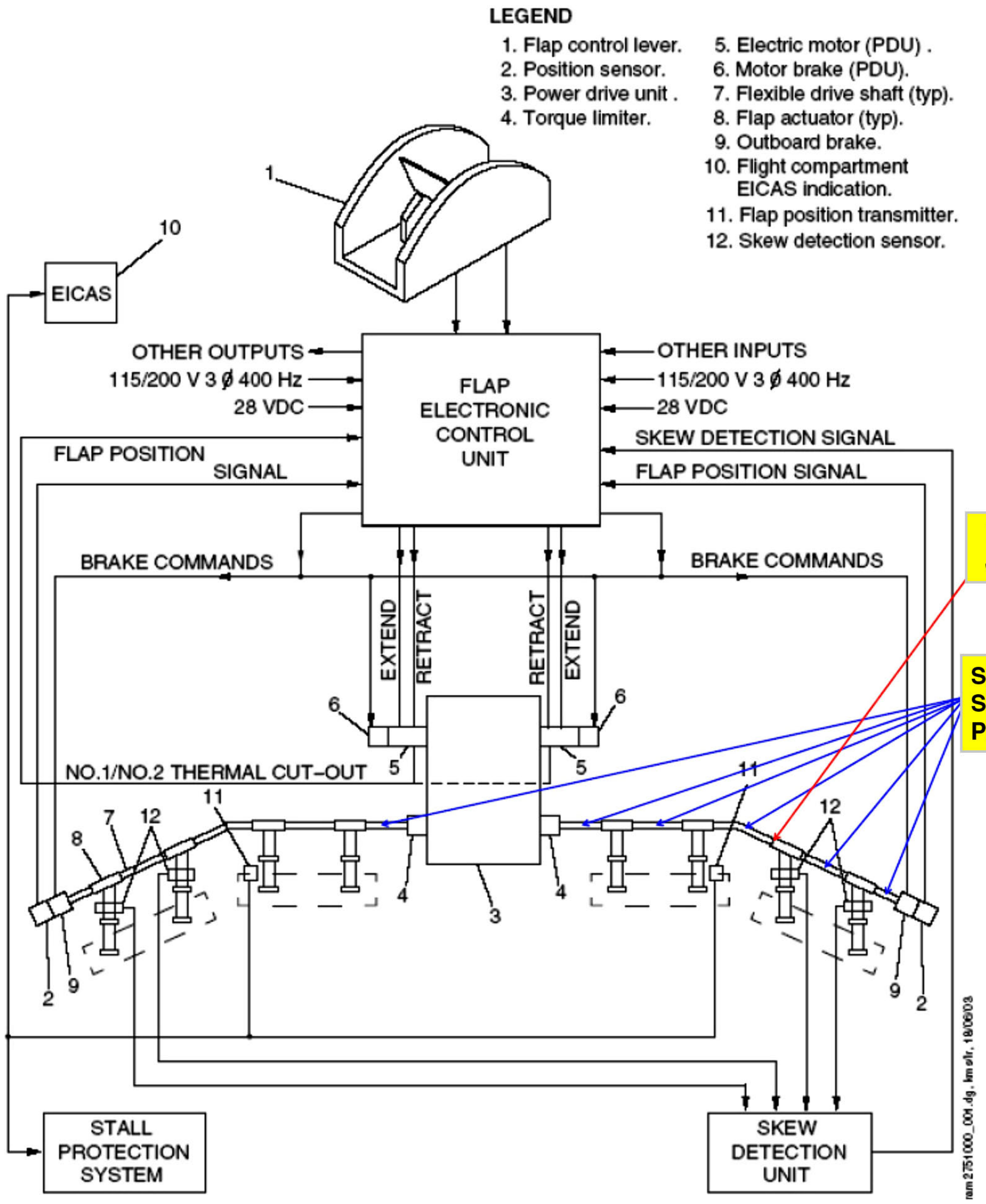


Figure 4. Flap system schematic

1.16.3. *Prior events, Airworthiness Directives and other documents*

In 1998 an Airworthiness Directive was published (CF-1998-14R4) warning of faults with becoming twisted flaps panels. In subsequent years, both in Canada and the United States, it was noted that the high number of malfunctions reported affecting the flaps system on the CRJ was pointing to an increased frequency of occurrences.

After an incident in which the flaps of a CRJ-100 were stuck in the 45° position just as the aircraft had to perform a go-around and proceed to the alternate, where it arrived with only 500 lb of fuel, there was renewed worldwide concern over the conditions of this system in this fleet. This incident occurred on 21 November 2006, two months before the accident that is the subject of this report.

As the initial response to that incident, while the investigations were still ongoing, Canada's TSB published a document on 21 February 2007, Board Concern A06Q0188-D1-C1, just like the FAA had done in publishing SAIB (Special Airworthiness Information Bulletin) NM-07-26 in April 2007. The latter details how water intrusion into the flaps system components, and subsequent freezing, seems to be a significant factor in incidents related to flaps failures in cold-weather operations.

TSB Canada's BC (Board Concern) and the FAA's SAIB warned of the dangers posed by possible failures of the flaps due to the increased landing speeds and the need for longer runways in case of flaps stuck in the retracted position, as well as of the dangers of excessive fuel consumption in the case of a dirty configuration with the flaps stuck in an extended position, which could lead to fuel starvation. A new AD had been scheduled for issue before September 2007.

1.16.4. *Safety actions taken following the accident*

Transport Canada issued airworthiness directive CF-2007-10 on 18 July 2007 to address the flaps system problems for this type of aircraft. The FAA subsequently published AD 2008-01-04.

At a later date, on 25 August 2008, Transport Canada issued a revision to that directive, CF-2007-10R1. The preamble states that the reason for the directive is the fact that the Bombardier CRJ-200 has an ample history of flaps system failures, though the directive makes no specific mention of the origin, ice, of some of the malfunctions. The nature of the faults is linked to the design and reliability of some of the flaps system components.

So as to diminish the risk exposure resulting from possible failures of the flaps system, the required compliance actions introduced by this directive aim to improve the reliability of the flaps actuators by replacing the internal seals, modifying the temperature limits and limiting the air speeds for operation of the flaps.

Moreover, the revised directive introduced additional maintenance requirements due to ongoing reports of flaps failures, as well as requirements for warning labels in the cockpit associated with the new operational limitations.

The corrective actions indicated by the directive are grouped into four main parts and two additional complementary parts:

- Part I includes changes to the AFM with the new temporary operational limitations, and communications and instructions for flight crews and dispatchers.
- Part II defines the more restrictive operational procedures posed by the possible failures of the flaps system. Among the possible failures considered is the flaps being stuck in the retracted position, leading to a landing with zero flaps.
- Part III requires flight crew training on procedures for dealing with possible flaps failures, and an annual simulator exercise to practice landing with zero flaps.
- Part IV introduces specific modifications, pressure and bending tests for the actuators, as well as new maintenance procedures for cleaning and greasing. It makes reference to SB 601R-27-150 and SB 601R-27-151.
- Additionally, Part V establishes the requirements for dispatching flights following a reported failure of the flaps. After a flaps fail message, the continuation of flights is subject to the following conditions:

  A) Appropriate maintenance actions must be performed in accordance with the Fault Isolation Manual (FIM, 27-50-00) prior to further revenue operations.
  B) If maintenance resources are not available, but normal flaps system operation can be restored after an on-ground reset, continued revenue operations can continue without any maintenance actions for a further ten flights, subject to strict dispatch conditions, which include no repeat occurrence of the fault, in which case only one more flight (non-commercial) is permitted, to a maintenance base where repairs can be made in accordance with the first section.

- Part VI defines the cockpit warnings and labels pursuant to SB 601-R-11-090.

The FAA issued airworthiness directive AD 2009-06-12, effective April 2009, which replaces the prior directive (AD 2008-01-04) issued by that agency on this topic.

The MEL for the dispatching of flights with a fault of the skew detection system has been modified, in accordance with the Airworthiness Directive, so as to determine the possible origin of the malfunction before starting a new flight and to ensure the absence of any previous "Flap fail" warning messages.

1.17. Organizational and management information

1.17.1. *Operating procedures in the company's manuals*

Flap fault

The PRM (Air Nostrum Pilots Reference Manual) warns that in case of a landing with 0° flaps, it is advisable to be set up on final before reaching the 10 nm fix ahead of the runway, and to adopt the landing configuration before starting the descent on final. The touchdown must be firmer than usual since a short flare will be required in order to avoid floating. A higher nose up attitude than normal is to be expected.

It states that in case of a flaps failure, they should be left in the failed position without attempting further movements.

If the flaps are not extended, they remain at 0°, the three hydraulic pumps must be turned ON manually, and the pitch-feel control system will not adjust the pitch feel control system for flap extension.

The GPWS Flaps Override button must be pressed.

Landing

In keeping with normal operations, on an ILS approach, the PF must request the extension of the landing gear at a specific position within the glide slope, and the PF must select and announce "gear down and locked". On intercepting the slope, the PF must request the landing checklist and the PNF must remind him to execute it prior to flying over the final approach fix (FAF).

Use of the interphone (headsets with headphones and microphone)

EU-OPS Regulations specify the obligation to install an interphone system for crews on those aircraft requiring a flight crew of more than one person. It likewise establishes the requirement to install them for operations on aircraft with a Maximum Weight in excess of 15,000 kg or with seating for more than 19 passengers.

The latest OPS part 1 included on the Regulations CE n° 859/2008 of 20th August 2008, already requires the use of headsets for flight crew member, as it is specified in OPS 1.313, "Use of headset".

"a) Each flight crew member required to be on flight deck duty shall wear the headset with boom microphone or equivalent required by OPS 1.650 (p) and/or 1.652 (s) and use it as the primary device to listen to the voice communications with the air traffic services:

- On the ground,
- When receiving the ATC departure clearance via voice communication,
- When engines are running,
- In flight below transition altitude or 10000 feet, wich ever is higher, and,
- Whenever deemed necessary by the commander.

b) In the conditions of paragraph 1 above, the boom microphone or equivalent shall be in a position which permits its use for two-way radio communications."

The operator's Operations Manual recommended as a precaution that the interphone be used on all flights when below 10,000 ft, including during engine startup and shutdown operations.

In July 2008 it was included in the OP(A) 8.3.0.C.6 the mandatory use of headphones with adjustable boom microphones during all operations below 10,000 feet. This mandatory use of the interphone is also intended for all operations below 10,000 feet including engines start and stop, as a preventive measure, in the PRM 1.2.0 page 3, as from November 1st., 2008

1.17.2. *Flight crew training*

The ongoing training provided by the operator to its flight crews includes periodic type rating, refresher and re-training courses for the corresponding airplane, as well as courses for advancement to captain for those copilots who are going to be assuming the captain's duties. These courses are offered while bearing in mind the fleet they are flying, the function they are exercising on it and the relevant time periods involved.

The pilots that made up the crew on this aircraft had successfully completed the following training:

The captain had taken a CRJ-200 type rating course in January 2003, a periodic CRJ-200 re-training course in November 2003, another periodic re-training course in December 2004 to revalidate his CRJ-200 rating, a periodic re-training course in November and December 2005, and a captain advancement course for the CRJ-200 in October 2006.

The copilot had taken the ATR-72/500 type rating course in June 2003, an ATR-72 periodic re-training course in May 2004, another periodic re-training course in May 2005, and the CRJ-200 type rating course in August 2006.

1.17.2.1. Course characteristics

The ATR-72-500 periodic refresher or re-training course is spread over four 6-month cycles for completion in a maximum of two years. The first and third of these cycles are complemented by a CRM refresher given by the psychology department, though no information was available on the contents or syllabus for this subject, nor on how it was evaluated.

The ATR-72-500 rating course consists of two phases: ground and simulator. Training in CRM is included in every simulator session, though there is no mention of how to apply the subject and the instructor is not given regulations to establish the criteria for a right assessment.

The course for advancement to captain is divided into four phases: ground training, simulator training, training on an actual flight and in-flight training under supervision. The CRM syllabus lists the following general aspects to be covered during the ground training phase:

a) Leadership as a management style,
b) Communication and coordination,
c) Error chain,
d) Effects of automation on CRM,
e) Coordination: The crew as a group,
f) Situational awareness,
g) Workload management: Fatigue and stress.

The CRJ-200 rating course consists of two phases: ground and simulator. None of the objectives specified for the training program include the CRM practices in the simulator sessions, so the instructor is not given an instrument with the criteria for their right assessment.

The CRJ-200 refresher course had been improved recently and had been approved by the DGAC in August 2006. It includes four phases: ground training and refresher, flight simulator training, training on emergency and safety equipment, and CRM. The program is taught over three cycles, each of which is associated with an annual refresher such that all of the airplane systems are reviewed over a three-year period. The CRM syllabus includes:

a) Human error and reliability,
b) Stress, stress management, fatigue and vigilance,
c) Situational awareness,
d) Decision making,
e) Coordination and communication in and out of the cockpit,
f) Leadership and teamwork. Synergy,
g) Automation and philosophy on the use of automation,
h) Company safety culture, operational procedures and organizational aspects,
i) Actual case studies. Analysis of the company's own incidents.

1.17.3. *Internal corrective actions taken by the company*

The operator's maintenance department has issued two memos to maintenance technicians reminding them of the actions to be taken in case of problems with a flaps fault.

The interval between inspection, cleaning and lubrication tasks for the flaps system flexible shafts has been reduced to 2,500 flying hours, versus the 4,000 specified in the manufacturer's maintenance program.

As regards annotations of faults in the Flight log, the criteria of Airworthiness Directive CF-2007-10R1 are being followed, as are the dispatch procedures, crew simulator training and other stipulations defined in the directive.

The maintenance actions and modifications specified by directive CF-2007-10R1 have been either implemented or are scheduled for completion within the required timeframes.

The instruction department adopted among the instruction objectives for 2008 the following items:

- General: Corrective measures of incidents occurred in flight operations. An increase of the demand levels in all the evaluations and CRM.
- Simulator: Flaps Fail at 0ª after takeoff training and actual landing distance calculation. Crew responses to GPWS warnings.

The identification of all acoustic and light warnings was included in the PRM 2.2.0, as well as the actions required in each case and the tasks distribution among the crew.

Recommended responses to EGPWS alerts were included in the PRM 2.2.3.

The operator indicated that it is a usual requirement that the crew assure the touchdown with the landing runway always within the TDZ during all the simulator training sessions as well as in the line inspections.

In the PRM 1.1.8 it has been included an expanded check list (with a guide to perform a complete preflight briefing) and in the PRM 1.2.3 the concept of identifying the "primary hazards" during the different operational briefings.

Concerning the CRM training they indicated that a communication in the cockpit course is carried out, which collects the following requirements: standard phraseology, explicit and implicit communication, direct and indirect questions and TEM analysis of the communications.

1.18. Additional information

1.18.1. *Crew statements*

The crew statements given after the accident provide information on the following details concerning the timeline of the operation:

Declaration of abnormality

- When the flap lever was selected to the first notch, corresponding to 8°, the EICAS “Flap Failure” message was received.
- The PNF noted there was a discrepancy between the selected 8° position and the position indicator, which read 0°.

Flight crew actions

- The copilot informs ATC of the flap fault.
- The pilot asks the F/O to press the EGPWS flaps override button to prevent its automatic flaps configuration warnings, “TOO LOW, FLAP”.
- The F/O reads the procedure in the QRH.
- The pilot decides to continue the approach. He realizes that a higher speed must be selected and that the required runway length is far below that available.

Final approach

- The captain decides to remain as PF given the delicate approach to be conducted, since the speed had to be kept between the 170-kt landing speed and below the 182-kt maximum tire speed.
- The “TOO LOW, GEAR” announcement is heard. None of them identifies it.

Landing

- As they initiate the landing, both realize that they have forgotten to lower the landing gear.
- The contact with the runway is smooth.
- The touchdown point is slightly to the left of the runway centerline and just after the intersection with runway 02-20.
- The captain verifies that he has directional rudder control so as to maintain reasonable control over the direction of the landing run.
- The crew confirms sufficient positive deceleration that will allow them to stop before reaching the end of the runway.

Emergency declaration

- An emergency was not declared since they were unaware that the landing gear was not down.

- For the same reason neither the two cabin crew nor the passengers were informed.

Evacuation

- When the aircraft stopped, the F/O read the evacuation procedure and both front doors were opened.

The crew helped the passengers leave the aircraft and directed them to move away from the aircraft.

2. ANALYSIS

2.1. Flight preparation and execution. Flap fault

The aircraft had experienced various intermittent faults of the flaps system on the preceding flights. On the two previous flights, the crews had been forced to conduct an abnormal landing operation with 0° flaps. The landing operation without extending the flaps is not considered an emergency operation. The aircraft is capable of handling that operation safely if enough runway length is available, but it cannot be considered a normal operation, as it does entail additional risks, as will be discussed later. As a result, the Minimum Equipment List (MEL) specifies that the flaps system must be operative for the airplane to be dispatched.

In Valladolid, where the operator does not have a maintenance service, the crew itself satisfactorily conducted ground tests, which encouraged them to continue with the flight despite the possibility that the intermittent fault would reappear once more. In their favor was the long runway at Barcelona, in case the fault should reappear, which they took as a likely probability. The experience of the captain, who had already gone through the same scenario on one occasion, along with the preparation and review of the procedures, settled the decision to start boarding and the operation.

The airplane took off with 8° flaps normally. The climb was begun and the flaps, which worked normally again, retracted. During the stopover in Valladolid, there were no problems with icing on the wings, though inside the sheaths housing the flexible shafts that transmit power to the flaps, the temperature could have been close to the freezing point of water. Once at cruising level, FL300, temperatures of –35 °C were encountered, as recorded on the DFDR, for about 25 minutes.

The investigation into the system and the inspection of the disassembled components revealed the presence of water, which was contaminating the grease that lubricated the flexible shafts, and even of the defective seal through which the water could have penetrated via shaft segment 4. After the exposure to low temperatures during the cruising phase, ice formed which seized the rotation of the flexible shaft which transmits the power necessary to extend the flaps.

At the conclusion of the cruising phase and once near their destination, the aircraft descended and started its approach to Barcelona. Four minutes before landing, the aircraft turned to intercept the ILS localizer, with help from ATC under radar contact. At that time, as the flaps lever was actuated by selecting 8°, the 'FLAP FAIL' warning was received. The flaps had seized, possibly due to ice formed by the water that had contaminated the system.

The system for protecting against asymmetrical (skew detection system) or uncoordinated operations of the four surfaces took over, stopping subsequent movements of those surfaces through the BPSU. In keeping with flight procedures, that condition should be maintained until landing, without attempting any further manipulations of the flaps lever, which could give rise to an asymmetrical condition that could affect the control of the aircraft.

Flight ANS-8665 was already on final and was preparing to land, having been cleared by ATC, which had been notified of the fault. The fault required the aircraft to keep an elevated approach speed in excess of 170 kt.

2.2. Approach maneuver into Barcelona

During the flight, as the crew had anticipated a possible flap fault repetition, they had eventually discussed and assessed the abnormality and had prepared for a landing operation without flaps, reviewing the abnormal procedures. Anyhow, they did not take the precautionary step of an early flap extension during the descent, in order to have more time for normal procedures tasks execution and to identify unforeseen circumstances.

On final approach, it is noticed, that the airplane accurately maintained the track and the proper speed on the glide path. The hydraulic system had been configured with all pumps running, as per procedure, and the "GPWS - FLAP OVRD" button had been pressed. Under those conditions, the "TOO LOW FLAP" warnings are inhibited. These warnings are received in normal operations when the flaps are not extended for landing.

At that moment, the captain (PF) asked if everything was done. There is no indication that the before landing checklists were completed.

There was a moderate crosswind and the preceding aircraft had reported windshear. The crew was focused on their special procedures, wind conditions and the flow of communications between ATC and the five airplanes that were in the approach and landing phases at that time. Seconds before touchdown, the EGPWS TOO LOW MINIMUMS, TOO LOW GEAR, TOO LOW TERRAIN and SINK RATE warnings sounded.

The TOO LOW GEAR warning sounded fifteen times, as heard on the CVR recordings, but it was not identified by the crew, which probably confused it with the 'TOO LOW FLAP' warning that would be normal for the flaps configuration present had that warning not been inhibited by pressing the override (OVRD) button. These warnings coincided with the aural warning for the gear not locked.

Though the crew performed the flight preparation prior to takeoff from Valladolid, given the likelihood of a problem with the flaps on approach, they did not manage afterwards to take into consideration that the "TOO LOW, FLAP" warning should not be received, and thus should not have been confused with the "TOO LOW, GEAR" warning. This fact can be considered as a deficiency in the training and skill of the crew, specifically as concerns a detailed knowledge of the indications associated with any of the aircraft's systems. A SR is issued in this regard to the operator to reinforce and improve its crew training in the knowledge and use of aircraft systems and their associated indications under normal, abnormal and emergency conditions.

Indeed, in a flaps retracted configuration, the usual warning of "TOO LOW FLAP" could not be issued for two reasons: first, as already noted, because it had been inhibited previously by pressing the "FLAP OVERRIDE" (OVRD) button; additionally, in this case, by keeping the landing gear retracted, this warning will not show up since mode 4B, which generates it, requires that the gear be extended.

There were fifteen GPWS warning repetitions between 500 ft and touchdown, with the constant presence of the gear unsafe horn in the background. It is obvious that, either from excessive concentration or from believing they were not relevant, the crew did not manage to identify the airplane configuration properly.

Onboard systems warnings should always be clearly identified. In addition, the warnings that are given by the EGPWS on final approach, should demand corrective actions. When the warnings repeat several times or escalate in seriousness, the possibility of a missed approach should be considered as the most appropriate maneuver. Indeed, the concept of 'stable approach' includes a proper airplane configuration and completed briefings and checklists, in addition to other aspects, including the path and speed being within specified margins. As a result, when repetitive EGPWS warnings appear, this means that there are continuing deviations beyond the margins, or a configuration fault, either of which would require to discontinue the approach and proceed to a go around.

Situations have occurred in which, faced with multiple and constantly repeating aural and visual warnings, as was the case here with the combination of TOO LOW GEAR, TOO LOW TERRAIN and SINK RATE warnings, plus the gear not locked horn in this case, the crew still believes the flight to be controlled and continues with the flight sequence as planned. For all above, and despite the corrective measures already adopted for the operator instruction department indicated in 1.17.3 a SR is issued to the operator to reinforce and improve its training so that during any phase of flight, and especially on approach, when a series of aural and/or visual warnings is received, the crews react proactively to interrupt the flight sequence (doing a go around on approach) so as to positively identify the warnings and retake control of the situation.

Crews should thoroughly identify every warning generated in the course of a flight, and specifically EGPWS warnings, as these usually appear in those phases of flight that entail more risk, such as approach. In these cases the performance of a go around maneuver should always be considered and, once completed, an effort should be made to identify the warning by analyzing the previous conditions. If the warning is not clearly identified, the crew is vulnerable since it does not know its cause. The cause must not be assumed, it must be identified.

It can be stated with almost total certainty that had a go around maneuver been performed in this case, the crew would have realized that the gear was retracted, since the go-around procedure ask for an airplane clean configuration, with gear-up, to optimize climb gradient.

2.3. Landing run

The airplane flew over the runway 25R threshold at an altitude of 50 ft and a speed of 180 kt. Its pitch angle was 6° with a slight yaw to the right to counteract the crosswind from 310° at 14 kt.

Fourteen seconds and 1,200 m from the runway threshold (300 m beyond the TDZ Touchdown zone), the aircraft, which had decreased its yaw angle to just one degree, lined up with the runway and touched the ground with its belly. The gear had not been lowered. The GS was 168 kt (172 kt IAS).

The initial contact with the runway was very soft and at a point 8 m left of centerline. From there the aircraft continued moving and skidding in a straight line until it came to a complete stop at the left edge of the runway after a 1,900-m run. There were only 250 m of paved surface left in front of the aircraft before the end of the runway.

The touchdown took place outside the touchdown zone (TDZ). As the aircraft did not run off the far end of the runway, this fact did not affect the accident, which it is considered to be due partially to the absence of the main landing gear, as with the gear down and locked, the touchdown would had taken place some meters before. On the other hand, the operator has confirmed that it is a usual requirement for the crew to assure the touchdown within the TDZ in all the simulator sessions and line inspections, so it is not considered necessary to insist in the improvement of this training.

As the airplane skidded, the yaw angle increased progressively to the 12° reached before coming to a stop. The long braking run is explained by the high initial speed of the skid, 168 kt, and by the uncommon ground effect resulting from the reduced height of the wings above the ground. At the start of the run, with the airplane still subject to lift, the effective coefficient of friction was barely 0.1. Then, with the entire weight of the airplane on the runway, the coefficient of friction rose to $m = 0.3$, which is representative of the friction between the aluminum and the asphalt.

The first friction mark was evident on the aircraft and was located in the rear of the fuselage, when the pitch angle was 6° and the yaw angle small. The final friction mark was on the central fuselage, with the airplane at a 12° yaw angle and level longitudinally.

The airplane did not depart the runway laterally, despite the presence of a crosswind. The ground spoilers did not deploy in automatic, since there was no rotation of the tires, and the reverse engine thrust was not used, possibly so as not to complicate the lateral control under crosswind conditions.

At a certain point during the run, when the crew realized that the gear had not been lowered, the lever was actuated to lower the gear, resulting in the abrasion of the doors and of the outboard tires on the main gear legs, which were damaged. Of course, the contact with the runway and the weight of the airplane kept them from lowering.

The evacuation was performed quickly thanks to the doors being opened rapidly and without problems, and to being very low to the ground. Both front doors were used, along with the emergency door above the right wing. The low height of the door frame above the ground, some 80 cm, was due to the absence of the gear and to having the airplane resting directly on its belly.

The fire and heat marks in the right landing gear wheel well, caused by burning traces of sealant and hydraulic fluid, along with the small fuel leaks detected, were indicative of a dangerous situation that could have been more serious had the fire propagated and spread out.

2.4. Reliability of flaps system

Although the immediate cause of the accident was the oversight in lowering the landing gear, it must be noted that it was a technical fault that detracted the crew's attention at a crucial moment. This technical fault, the anomalous operation of the flaps system and the seizing of its panels, was well known by the manufacturer and the operators alike. Board Concern A06Q0188-D1-C1, published not even a month after the accident, noted that a fault in the system could lead to distraction and oversights which could result in mistakes with potentially adverse consequences. The combination of these consequences with a high fault recurrence rate increased the potential for possible accidents or incidents. The aforementioned document in fact admitted, following the incident of 26 November 2006, that flaps malfunctions were common, especially in cold weather.

Moreover, consideration must be given to the overhead added by a situation of constant malfunctions. The circumstances surrounding this accident call for reflection of the following details:

- The operator, being an important carrier with 35 airplanes of the type in operation for several years, knew of the type of fault.
- The Operations and Maintenance Departments of the operator had been informed of the difficulties posed by the performance of flights in this specific case.
- The aircraft's flight history revealed that it had been forced to land without flaps on three occasions.

- The same captain had already landed without flaps on another occasion.
- Other flights may have landed without flaps without this fact having been communicated and logged, as demonstrated by the cases of the last landing in Valladolid and Paris, meaning the historical maintenance records could be incomplete. This assessment is supported by the fact that the FECU memory had recorded many seizing events that were not reflected in the maintenance records.
- The maintenance actions in the preceding days, when the intermittent failure started to manifest itself, did not hit on the proper corrective action, possibly denoting a certain superficiality in the attempt to solve a recurring problem.

It can be surmised that the flaps anomalies were received with resignation among the crews, viewing the frequency of this failure. In this atmosphere, the crew felt capacity to continue with the flight despite the probable reappearance of the fault. By considering the situation normal, the number of times on which the flight could be initiated with this deficiency was multiplied, potentially increasing the risk of the operation.

A greater awareness of the importance of and adherence to the procedures would have resulted in the abnormalities being logged, and for said abnormalities to have been considered as defects preventing the dispatch of the aircraft and for effective maintenance actions to have been carried out. This approach could possibly have incurred greater operating costs and a larger number of deficiency reports, which would have driven the manufacturer to adopt suitable technical solutions.

Consequently, it should be recommended that the manufacturer look for those design or operational measures needed to restore and reinstate the system's reliability. Transport Canada, authority of origin in the design and manufacture of this type of aircraft, has already issued an Airworthiness Directive, CF-2007-10, in July 2007, revised in August 2008, CF-2007-10R1 (see Section 1.16.4, recently published Directives), for the purpose of decreasing the exposure to risks involving possible flaps system faults. As a result, a SR is not issued in this regard.

Secondly, the operator has reported (Section 1.17.3, Internal corrective actions taken by the company) that the actions already taken by maintenance and operations go beyond those required by the Airworthiness Directive. Two memos were issued to maintenance technicians reminding them of the actions to be taken when faced with problems involving flaps faults. The interval for the inspection, cleaning and lubrication of the flexible shafts was reduced, and is performed by Air Nostrum every 2,500 flying hours versus the 4,000 h in the Bombardier maintenance program. As for annotating faults in the flight logs, the new criteria in the Directive are being followed. On this point, such progress could be extended to other anomalies and technical issues which could surface in the course of operations. The record in this case has exhibited a certain laxity in terms of incorporating those annotations into the flight logs. As a result, a SR is issued to the operator to improve its internal system for detecting and identifying faults.

2.5. Operating procedures

It is worth noting that the immediate cause of the gear-up landing accident was a failure to actuate the landing gear lever. This is a human error. The attention focused, channeled, concentrated on the malfunction and on the specific procedures for combating the fault led to a failure to execute the normal procedures.

The normal operating sequence, of extending the flaps up to 20° during the initial approach, followed by and the deployment of the landing gear, with the path already captured was broken when the ‘FLAP FAIL’ warning appeared. Afterwards the approach proceeded ahead without extending the gear and without the crew been aware of this condition. From this moment on, the attention was focused on managing the abnormality.

A landing without flaps forces the crew to set up the airplane so as to bypass superfluous GPWS warnings and to establish reserve hydraulic power to help with the controls. The procedures state greater control forces than usual should be expected when landing at the speed corresponding to 0° flaps. Likewise, the airplane’s pitch attitude changes with respect to the one it assumes on approach with 45° flaps. The speed that the PF must maintain and the PNF monitor is by a 25% higher than the normal landing speed.

Operating procedures must be established to avoid oversights, to include the following:

- Lower the flaps sooner if they are likely to fail so as to have more time to carry out the associated Abnormal Procedure, prepare for the approach and give a complete briefing that takes every aspect into account.
- Distinguish between the ensuing stages of a malfunction: identify and assign tasks, complete the steps to be taken and reestablish the duties associated with normal operations.
- Delay the approach until the Abnormal Procedure is completed and duties are assigned as per normal operations.

From the above it follows that the crew was unsuccessful in resuming their normal tasks, after completing the abnormal procedure for a failure of the flaps system, missing the execution of items related to the configuration and the pre-landing normal procedures. Afterwards, when the relevant warnings and announcements appeared, both pilots dedicated most of their attention to the flap system abnormality and erroneously assumed that all the warnings were related to the technical fault paying no attention to the meaning of each of the warnings. Then they lost sight of the overall picture and did not monitor the approach and landing maneuvers, resulting in forgetting the corresponding procedures. As a consequence, a SR is issued to the operator to reinforce and improve its crew training in this respect.

2.6. Human factors aspects

Focused as they were on piloting, the before landing checklist was not completed, even though the captain asked, "Then everything is done, right?" referring to preparing the airplane for the imminent landing. This question is ambiguous and the expected answer is implied, and thus it fails to convey any requirement or interest in obtaining a meaningful answer.

In strict adherence to standard phraseology, it would have been preferable to ask a question that was both specific and direct, such as, "Is the flap fail procedure complete?", "Is the landing list done?".

Courses and texts on CRM introduce the concept of "effective communication", defined as: "Communication which succeeds in conveying the totality of the message intended by the sender". Proper communication also includes the scrupulous use of call outs and standard aviation phraseology, reading warnings exactly as they appear, naming procedures, etc.

In this regard, and although the operator has already carried out a communication in the cockpit course, as indicated in paragraph 1.17.3, a SR is issued to the operator to reinforce and improve the training of its crews on the use of standard phraseology and communication in the cockpit such that questions are concise and direct, requiring clear and unequivocal answers.

The CRM training the operator provides to its crews, does not seem to be sufficiently apreciated as regards as the assessment of its weight and importance in the flight personnel environment. CRM is a subject requiring even more emphasis from the operator due to its recent implementation, if its lessons are to be thoroughly learned by the crews. In the rating and refreshment courses documentations, revised, CRM themes seem not to be conveniently appraised, as this matter seems to be passed by simply attending the classes. Instead they should be regarded as deciding themes and practices for course overcoming.

It was noted that the operator includes an ample CRM syllabus for certain training courses, but of greater importance still is the emphasis placed on this subject and on how it is graded so that it is given the importance it merits. In this regard, it would be worthwhile to have a detailed instructor guide and clear evaluation criteria. As a result, and since various aspects of CRM were noted as possible factors influencing the chain of errors, a Safety Recommendation is issued so that the operator reinforce the CRM training it provides its crews and improve their evaluation, considering the CRM practices at the same level of the theoretical exams and/or the essential maneuvers in the simulator.

The cockpit workload was accompanied by a relatively high number of radio communications and by concern over possible windshear reported by a preceding airplane. The checklists exist precisely so that in times of stress, when memory is prone to failure, the steps to be taken are not overlooked. Training should stress that it is during extraordinary situations when there is a greatest need to follow established procedures, such as performing and using checklists.

Aside from not having completed the checklist, the crew did not hear or confused the repeated 'TOO LOW GEAR' warning with 'TOO LOW FLAP'. Nor did they identify the horn warning that the gear was not down and locked. Since the warnings are input directly to the cockpit crew by the interphone, there is a doubt concerning whether the use of headsets by the crew would have allowed any of these warnings to be identified had they been isolated from the noise of the cockpit and been heard with greater clarity.

In addition, it must be noted that the crew consisted of a recently promoted captain and a copilot with little experience on the airplane. If in the cockpit of this aircraft, a crewmember with ample experience in the post, had been present, a different sequence of events would possibly have resulted, well through the delegation of tasks, or through the communication between the crew, or at the resumption of normal operations after correcting the anomaly, or through the identification of aural warnings. Since, experience offers great protection against faults or oversights, it is assumed that a more experienced crew could have broken the chain of errors observed in this event, therefore, a SR is issued to the operator to revise and improve its crew schedules so as to ensure that its crew compositions are balanced in terms of their combined experience.

3. CONCLUSION

3.1. Findings

- Flight ANS-8665 was dispatched from Valladolid to Barcelona with certain intermittent anomalies in the actuation of the flaps.
- The aircraft encountered temperatures during the flight of about –40 °C, normal for the season and flight levels in question.
- The flaps did not extend for landing when commanded by the crew.
- During the post-accident disassembly, it was discovered that water had mixed in with the grease inside the sheaths housing the shafts that actuate the flaps, meaning the seizure was probably caused by ice blocking the rotation of the flexible shafts.
- The manufacturer, the certifying authority and the operator were aware of this problem with the flaps system, which even occurred with some frequency during cold weather operations with the CRJ-200.
- The aircraft landed with 0° flaps, which implied high approach and landing speeds and specific system configurations.
- There were high traffic and communication densities at the destination airport.
- The wind was from the right and there had been a report of windshear by the preceding airplane. The runway was dry, the sky was clear and visibility was in excess of 10 km.
- The before landing checklist was not completed and the landing gear was not lowered.
- During the final approach leg there was a flood of aural EGPWS warnings along with the warning horn for the landing gear retracted, which the crew was unable to identify the anomalies and thus take proper corrective actions.
- The airplane landed gently on its belly, aligned with the runway and 8 meters to the left of centerline.
- The initial contact was made some 1,200 m from the runway 25R threshold, and the aircraft skidded for 1,900 m, meaning the actual landing distance was 3,100 m.
- The aircraft stopped inside the runway at its left edge and 250 m from the end.
- There was no visible fire on the outside of the aircraft and the structure maintained its integrity.
- A fire broke out in the wheel well, but it remained confined to this space and eventually went out.
- The passengers and crew performed an emergency evacuation in the middle of the runway. Two persons received slight bruises during the evacuation.
- The firefighting service immediately proceeded to the scene and sprayed fire retardant foam on the belly of the airplane.
- The aircraft suffered abrasion damage from the runway to the flaps guards, the main gear doors and the skin on its underside which affected the primary structure.

3.2. Causes

It is considered that the omission to actuate the landing gear extension lever, before touchdown, was the direct cause of the accident. Consequently, a belly landing in a gear-up configuration followed.

A contributing factor was the presence of certain technical anomalies in the operation of the flaps system which detracted from the attention of the crew.

4. SAFETY RECOMMENDATIONS

As a result of many flap fail occurrences and a serious incident that occurred on 21 November 2006, the manufacturer of the aircraft, Bombardier, conducted a general review of the flaps system on CRJ airplanes in cooperation with Canada's aviation authority. Airworthiness Directive CF-2007-10 was issued in July 2007, and subsequently modified in August. It established various actions in the areas of documentation, operations, maintenance and crew training. This measure aimed to address the continuing deficiencies present in the system so as to diminish the risks associated with flaps failures, which in this accident was considered a contributing factor; hence no safety recommendation is issued in this regard. As a result of the accident, the following safety recommendations are issued:

REC 33/09. In light of the deficiencies found in the operation of the aircraft, it is recommended that the operator reinforce and improve the theoretical and simulator training of its crews which will allow them to proactively and appropriately cope with critical flight situations, when concurrent acoustical and visual warnings occur, reacting in such a way that they can be able of:

- breaking and interrupting the normal sequence of normal tasks,
- unequivocally identify the warning and the flight condition,
- perform the tasks and procedures related to the specific abnormality,
- Resuming the previously interrupted sequence of normal tasks and procedures.

In the critical approach flight situations, when the concept of stabilized approach applies, it should be born in mind the convenience, and may be, necessity, of discontinuing the approach, initiating a go-around in order to retake the optimal control of the situation before reaching the ground.

The training must extend and encompass the knowledge and the use of airplane systems, and the associated collection of warning and indications related to their functioning, in any normal , abnormal or emergency situations.

REC 34/09. Due to the contribution that various aspects of CRM had played in the course of this event, and to the appreciated deficit of appraisal of these CRM matters in the training provided by the operator, it is recommended to reassure, reinforce and improve the assessment and importance of CRM matters in the training syllabus of its crew, in general, and specifically, on the following aspects:

a) The resumption and assignment of normal tasks once the abnormal or emergency procedures are completed so as to avoid having both crewmembers focus their attention on the anomaly and lose the ability to monitor and to see the overall picture.
b) The use of standard cockpit phraseology and communication, avoiding ambiguity and colloquialisms.

REC 35/09. It is recommended that the operator revise and improve its crew scheduling and planning, so as to ensure a high level of compound experience, gathered by the pilot and copilot, in every team.

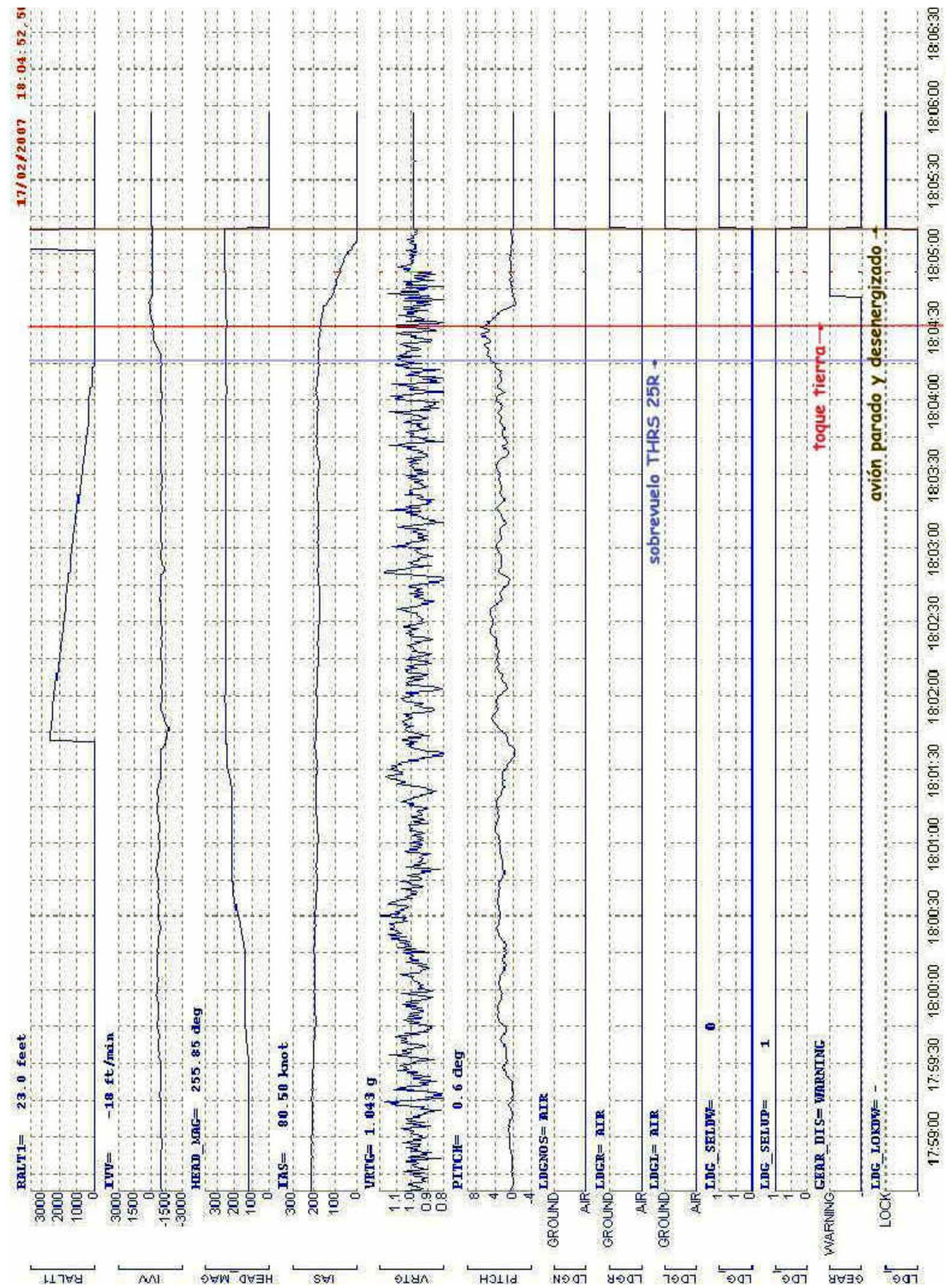
REC 36/09. It is recommended that the operator revise and improve the stablished procedures for detecting, tracking, correcting and controlling the faults, malfunctions and defects that use to arise in the course of operations.

APPENDICES

APPENDIX 1
Load and balance sheet

```
DVC-16377 1243 24JAN07
.
L O A D S H E E T                CHECKED              APPROVED      EDNO
ALL WEIGHTS IN KG          LIC OPS-VL/L                               01
.
FROM/TO FLIGHT           A/C REG VERSION           CREW      DATE     TIME
VLL BCN IB 8665          ECIBM    R50              2/02      24JAN07 1343
                              WEIGHT              DISTRIBUTION
LOAD IN COMPARTMENTS            319 1/319
.
PASSENGER/CABIN BAG            3360 40/0/0                TTL   40 CAB 0
                                    PAX 40                SOC
                                    BLK
TOTAL TRAFFIC LOAD             3679
DRY OPERATING WEIGHT          14771
ZERO FUEL WEIGHT ACTUAL       18450 MAX   19958           ADJ
TAKE OFF FUEL                  2600
TAKE OFF WEIGHT   ACTUAL      21050 MAX   23133           ADJ
TRIP FUEL                      1200
LANDING WEIGHT    ACTUAL      19850 MAX   21200   L       ADJ
.
BALANCE AND SEATING CONDITIONS          LAST MINUTE CHANGES
BI       61.61   DOI        42.99    DEST SPEC CL/CPT +-  WGT INDX
LILAW    28.74   MACLAW     14.17
LIZFW    33.11   MACZFW     15.90
LITOW    27.06   MACTOW     13.96
STAB TO  7.3    ANU - ALL FLAPS
   SEAT ROW TRIM
OA   7/OB 11/OC 12/OD 10
.
UNDERLOAD BEFORE LMC       1350               LMC TOTAL + -
--------------------------------------------------------------------------
```

APPENDIX 2
DFDR readouts


RALT1= 23.0 feet
IVV= -18 ft/min
HEAD_MAG= 255.85 deg
IAS= 80.50 knot
VRTG= 1.043 g
PITCH= 0.6 deg
LDGNOS= AIR
LDGR= AIR
LDGL= AIR
LDG_SELDW= 0
LDG_SELUP= 1
GEAR_DIS= WARNING
LDG_LOKDW= -
17/02/2007 18:04:52.5
sobrevuelo THRS 25R
toque tierra
avión parado y desenergizado
-150 -120 -90 -60 -30 0 30 60
segundos

APPENDIX 3
ILS approach plate for runway 25R in Barcelona

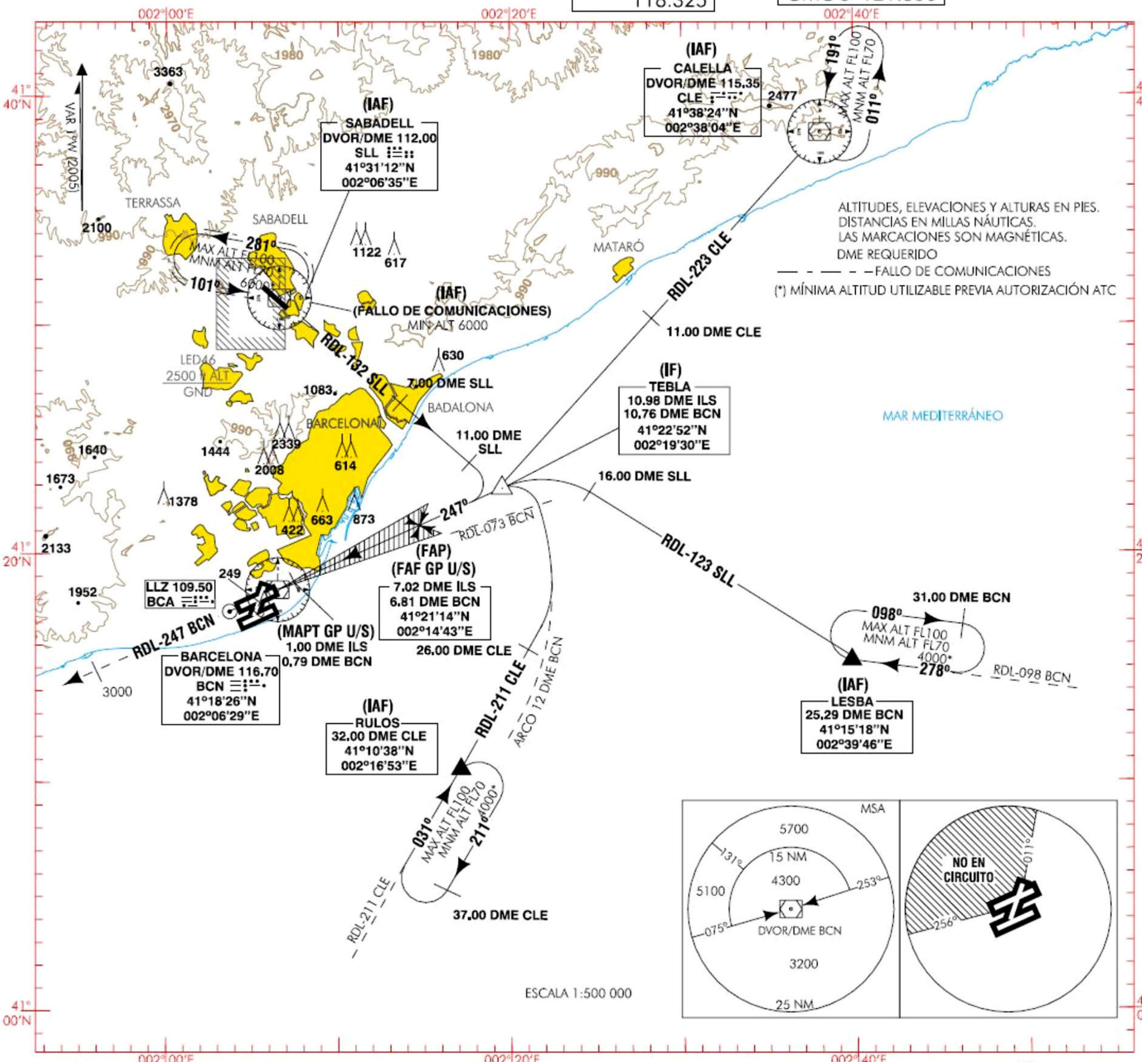
CARTA DE APROXIMACIÓN POR INSTRUMENTOS-OACI

ELEV AD 14

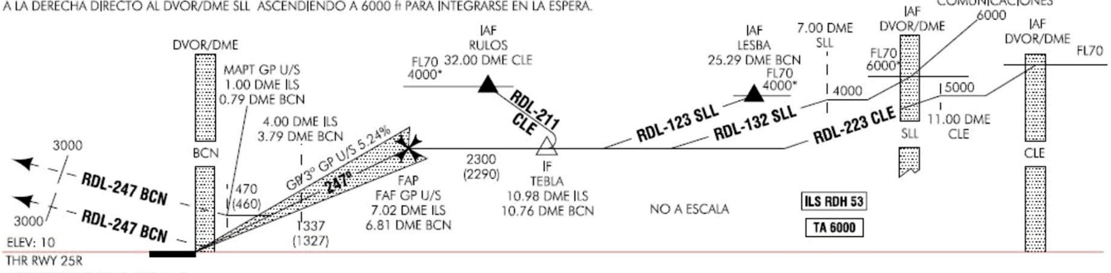
APP 119.100
ATIS 118.650
TWR 118.100
118.325

GMC E 121.850
GMC W 121.700
GMC S 121.650

BARCELONA ILS RWY 25R



FRUSTRADA: SUBIR EN RDL-247 BCN HASTA ALCANZAR 3000 ft Y ESPERAR AUTORIZACIÓN ATC.
FRUSTRADA FALLO DE COMUNICACIONES: SUBIR EN RDL-247 BCN HASTA ALCANZAR 3500 ft. VIRAR A LA DERECHA DIRECTO AL DVOR/DME SLL ASCENDIENDO A 6000 ft PARA INTEGRARSE EN LA ESPERA.



CAMBIOS: ALTITUD MIN ESPERAS, ANTENAS, COTAS, RENUMERACIÓN.

HGT REF ELEV THR RWY 25R

OCA/H		A	B	C	D
STA	CAT I	215 (205)	227 (217)	235 (225)	246 (236)
	CAT II	(97)	(114)	(125)	(140)
	CAT III	APPROVED			
	GP U/S	470 (460)			
En circulto (H) sobre 14		580 (570)	700 (690)	890 (880)	1300 (1290)

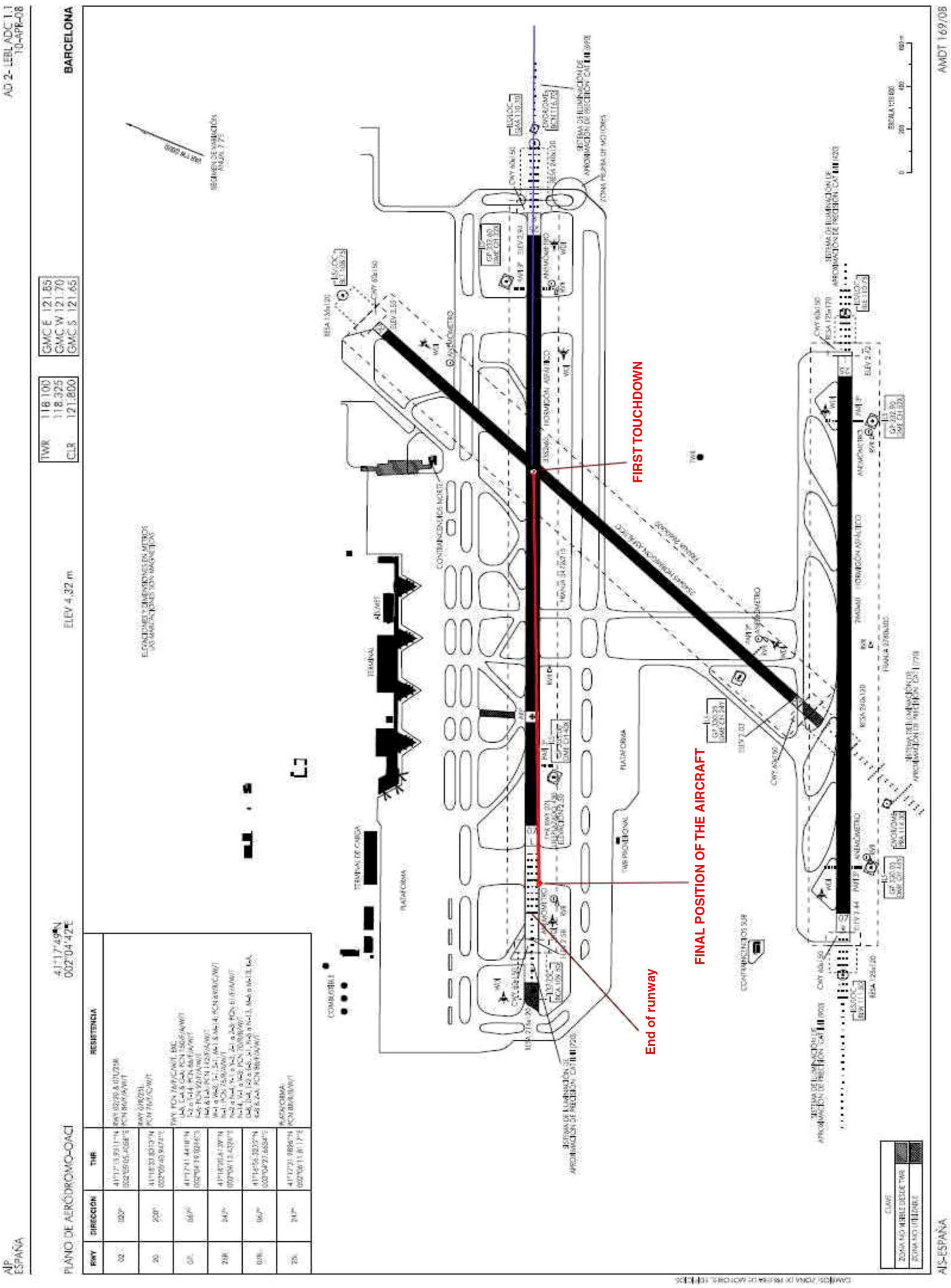
GS	kt	80	100	120	140	160	180
FAP-THR: 7,03 NM	min:s	5:16	4:13	3:31	3:01	2:38	2:21
FAF-MAPT: 6,02 NM	min:s	4:31	3:37	3:01	2:35	2:15	2:00
ROD: 5,24 %	ft/min	425	531	637	743	849	955

ALT/HGT DME (ILS) FNA GP U/S

13 DME	12 DME	11 DME	10 DME	9 DME	8 DME	7 DME	6 DME	5 DME	4 DME	3 DME	2 DME	1 DME
						2300 (2290)	1980 (1970)	1660 (1650)	1340 (1330)	1020 (1010)	700 (690)	

WEF 22-NOV-07 (AIRAC AMDT 14/07) AIP-ESPAÑA AD 2-LEBL IAC/9

APPENDIX 4
Diagram of Barcelona Airport and landing marks


FIRST TOUCHDOWN
FINAL POSITION OF THE AIRCRAFT
End of runway
BARCELONA
PLANO DE AERÓDROMO-OACI
ELEV 4,32 m
AIP ESPAÑA
AIS-ESPAÑA