Transportation Safety Board of Canada

Bureau de la sécurité des transports du Canada

AVIATION INVESTIGATION REPORT
A06A0096

TAKE-OFF PERFORMANCE CALCULATION ERROR

AIR CANADA
EMBRAER 190-100 C-FHIU
EDMONTON, ALBERTA
12 JULY 2006

Canada

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Aviation Investigation Report

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Summary

On 12 July 2006, an Air Canada Embraer 190-100 (registration C-FHIU, serial number 19000037) was being operated as Flight ACA1156 on a scheduled flight from Edmonton, Alberta, to Toronto, Ontario, with five crew members and 81 passengers on board. At 1011 mountain daylight time, the aircraft commenced its take-off. During rotation, the crew noticed that the aircraft pitch response was different than normal. The aircraft successfully climbed away and the flight continued and made an uneventful landing in Toronto.

Ce rapport est également disponible en français.

Other Factual Information

History of the Flight

The flight crew was scheduled for a 10-hour duty day, operating two segments. The first segment, from Toronto/Lester B. Pearson International Airport (CYYZ) to Edmonton International Airport (CYEG), was flown by the captain. A 45-minute turn-around was scheduled, followed by a return to Toronto.

On arrival in Edmonton, company maintenance staff had to power down[1] the aircraft to clear a secondary power distribution assembly (SPDA) fault message. Because aircraft servicing was to be completed with only battery power available, the captain had to oversee the refuelling operation and supervise the servicing of the lavatory system. The captain completed these tasks, while the first officer was completing the pre-flight walk-around inspection. After the power-down exercise, the SPDA fault message was cleared and the aircraft was declared serviceable.

For the return flight to Toronto, the captain was the designated pilot not flying (PNF) while the first officer was the pilot flying (PF). Company standard operating procedures (SOPs) require that the PNF calculate the take-off performance data using an on-board laptop computer commonly referred to as an electronic flight bag (EFB).[2] The thrust setting and take-off speeds are then to be verified by the PF, copied onto the operational flight plan, and then entered into the flight management system (FMS).

After completion of the walk-around, the first officer calculated the preliminary take-off performance data using the captain's laptop. The captain's laptop was used because the first officer's laptop power cord was defective. The captain's laptop had been left plugged in to ensure continued battery charging. However, the first officer had to reach over to the captain's side of the cockpit because the power cord on the captain's side was not long enough to reach to the first officer's side. All preliminary load information was entered. However, an error in the fuel weight was introduced when the first officer entered the weight of the fuel on board (FOB) at the time, which was 3700 kg, instead of entering the planned fuel for departure, which was 10 200 kg.

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1 Power down: Maintenance action that requires removal of power from aircraft systems.

2 Electronic flight bag (EFB): Electronic computing and/or communications equipment or systems used to display a variety of aviation data or perform a variety of aviation functions. The scope of EFB functionality may include data connectivity. EFBs may be portable electronic devices (PEDs) or installed systems. A PED is a self-contained electronic computing and/or communications device that is not permanently connected to any aircraft system, although it may be connected temporarily to an aircraft's electrical power system, externally mounted antenna, data bus, or a holding device such as a cradle.

The first officer then transcribed the resulting take-off performance data to a blank area at the upper right corner of the operational flight plan (see Appendix A). These data included the take-off weight (TOW), thrust setting, decision speed (V1), rotation speed (Vr), take-off safety speed (V2), flaps up speed (Vfs), and the stabilizer trim position. The transcribed data were 41 700 kg, 84.9, 137, 137, 140, and 186 with a stabilizer trim of 1.3 UP, respectively. Had the planned FOB weight of 10 200 kg been used, the resulting figures would have been 47 600 kg, 90, 149, 149, 151, 200 and 1.3 UP trim (see Table 1). When the captain returned to the flight deck, he assumed his PNF duties and proceeded to enter the preliminary performance figures into the FMS.

Data	Operational Flight Plan	Performance Figures	
		Required	**Used**
FOB*	10.15	10.2	**3.7**
TOW*	47.78	47.6	**41.7**
Thrust (N1)	–	90.0	**84.9**
V1	–	149	**137**
Vr	–	149	**137**
V2	–	151	**140**
Vfs	–	200	**186**
Stab trim	–	1.3 UP	**1.3 UP**
* indicates fuel in thousands of kilograms			

Table 1. Performance data

Approximately 15 minutes before departure, the captain was advised that the flight service director (FSD) was not on board. He then contacted the Station Operation Control (STOC) in an attempt to locate the FSD. Shortly thereafter, the FSD arrived.

The crew members received their air traffic control (ATC) clearance, and entered the navigational data into the FMS. As part of the pre-flight fuel check, they compared the fuel gauge indication (10.2 tons) with the operational flight plan required fuel (10.15 tons). They verified that the fuel sheet indicated the proper flight plan revision number, and completed the ACARS[3] pre-flight fuel check. The SOPs did not require that they compare the actual FOB with the FOB entry on the laptop computer take-off page. Consequently, no discrepancy was noted.

Shortly after initiating the before-start checklist, a flight attendant (FA) advised the flight crew that water was overflowing from a coffee maker. While the first officer communicated with the FA over the interphone to resolve the water overflow problem, the captain was advised by ATC that the departure runway had been changed, and that they would now be departing from Runway 12.

Because there had been a problem with the first officer's laptop power cord, the captain completed the changes using his laptop. He entered the new runway, temperature and altimeter setting, and recalculated the take-off performance data. By design, the system automatically transferred the fuel figure that had been initially entered (3700 kg), and used this figure for the new calculation. The new performance data generated were then compared to the previously calculated data and, because of the similarities, were accepted as valid. The captain did not identify either the incorrect fuel weight, or the incorrect take-off weight presented on the laptop take-off page. He then entered the new thrust and take-off values into the FMS.

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3 Aircraft Communication Addressing and Reporting System

When the crew members called ATC for clearance to push back from the gate, they were unable to contact either ground or tower control because those two frequencies were unserviceable. The crew members were eventually able to contact departure control. They received push-back clearance 10 minutes after the scheduled departure time. After engine start and release of the ground support crew, the crew requested, and received, taxi clearance for a departure from Runway 12.

During taxi, the crew received, and the first officer reviewed, the final load data on the ACARS. The final load data values were compared to the operational flight plan values listed at the bottom left of the operational flight plan, and accepted, because they were within the prescribed SOP tolerances. At no time were the final load data values compared to the EFB values that had been transcribed to the top right corner of the operational flight plan, nor was this required by SOPs.

The first page of the operational flight plan lists the planned block fuel, estimated zero fuel weight and estimated take-off weight at the bottom left corner. A designated area situated immediately right of these figures is used to transcribe the final load data. There is no specific area on that same page to transcribe the performance data calculated on the EFB. Crews normally transcribe these data to the top right corner of the page.

At 1011 mountain daylight time,[4] the aircraft took off from Runway 12. The aircraft was rotated at a speed of 140 knots, at a rate of 1.5 to 2 degrees per second, in a smooth and continuous motion. The actual lift-off occurred at 159 knots, eight seconds after the first up-elevator input to the flight control. During rotation, the crew noticed that the aircraft pitch response was different than normal. The aircraft felt as if it were out of trim and slow to respond.

The aircraft was not equipped with any device that would have provided the crew with an accurate and timely indication of inadequate take-off performance. Presently, there are no such devices certified for installation or use on civil aircraft. In recent years, considerable effort has gone into the development of a reliable means to detect inadequate take-off performance. Transport Canada (TC) created a team to continue to explore ways of building a take-off performance monitoring system using emerging technologies as proof of concept.

Once above 10 000 feet above sea level (asl), the crew members reviewed the performance data on the EFB and noted the discrepancy. They immediately advised company dispatch. The rest of the flight was uneventful. On arrival in CYYZ, the crew filed an Air Safety Report (ASR), as is required by the company to address safety concerns.

Weather

The Edmonton International Airport weather recorded at 1000 was as follows: winds 040° true at 10 knots, visibility 15 statute miles (sm), few cloud layers starting at 1800 feet above ground level (agl) with a ceiling at 11 000 feet, temperature 15°C, dewpoint 10°C, and altimeter setting 29.75 inches of mercury.

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4 All times are mountain daylight time (Coordinated Universal Time minus six hours).

Flight Crew

The crew for this flight was current and qualified and was experienced in airline operations. The captain had completed his training on the Embraer in April 2005. The first officer had completed training on the Embraer in October 2005.

Electronic Flight Bag

The Air Canada Embraer fleet is equipped with Class 1 EFB for determining performance calculations. This EFB is a stand-alone computer that does not share connectivity with aircraft systems. The EFB was introduced into line operations when the Embraer aircraft entered service at Air Canada. The EFB is a laptop computer using a Microsoft Windows®–based software application called Legato. The application was developed in house by a team of aircraft performance staff and technical pilots of the Air Canada Flight Operations Embraer team, and was approved for operational use by TC.

Take-off performance is calculated in Legato on the take-off page. This page was designed with a two-step calculation process to increase awareness of preliminary versus final load figures. The first calculation assumes that the preliminary figures for the upcoming flight are entered using the estimated zero fuel weight (EZFW) and the planned fuel on board (FOB) for the flight. The final calculation is completed when the crew receives the final load data.

Standard Operating Procedures

The SOPs for the Embraer were developed by a core team of experienced company check and training pilots, mainly from the Air Canada Regional Jet program. They used procedures provided by the aircraft manufacturer, SOPs from other Air Canada fleets, and procedures from other airlines operating the aircraft. As the SOPs were being developed, they were trialed in a simulator for appropriateness.

TC monitored the development and ultimately approved the procedures. This was done in accordance with the *Canadian Aviation Regulations*, specifically Section 725.138 of the Commercial Air Service Standards (CASS) and the associated guidance of Section 745.138. For the EFB, Commercial and Business Aviation Advisory Circular (CBAAC) 231, dated 20 July 2004, was used as guidance. CBAAC 231 is based on Federal Aviation Administration (FAA) Advisory Circular (AC) 120-71A. The Canadian standards and guidance material used for the SOP approval provides direction and advice that is primarily for content.

Other Occurrences

On 14 October 2004, a Boeing 747 cargo aircraft crashed on take-off from Halifax, Nova Scotia,[5] when the crew attempted a take-off with less than the required thrust and lower-than-required take-off rotation speed. All seven crew members suffered fatal injuries. The crew had used the incorrect take-off performance data that had been calculated on the on-board laptop computer using the aircraft weight from the previous take-off.

In June 2006, the TSB issued Recommendation A06-07 to TC stating that the Department of Transport, in conjunction with the International Civil Aviation Organization, the Federal Aviation Administration, the European Aviation Safety Agency, and other regulatory organizations, establish a requirement for transport category aircraft to be equipped with a take-off performance monitoring system that would provide flight crews with an accurate and timely indication of inadequate take-off performance. Although the installation of such a system in aircraft would not prevent data insertion errors from happening, it was seen as a physical defence that would assist the crew in identifying take-off performance data errors. Following this recommendation, TC formed a working group with the objective of exploring ways of building a prototype Take-off Performance Monitoring (TOPM) system.

On 10 December 2006, a Boeing 747-400 with 563 passengers and 15 crew members on board took off from Paris-Orly Airport, France, also using incorrect take-off performance data. Substantial damage occurred to the lower aft fuselage area when the aircraft over-rotated during the take-off. The runway was sufficiently long that the aircraft was able to become airborne and return for a safe landing. In this instance, the crew had used the aircraft zero fuel weight (ZFW) instead of the take-off weight (TOW) to calculate the take-off performance data.

Following the Paris-Orly occurrence, France's Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) organized a working group to study the issue of data insertion errors leading to take-off performance occurrences. The working group will be analyzing data from similar past occurrences. Taking part in this working group will be the Direction Générale de l'Aviation Civile (DGAC) of France, airlines and the Laboratory of Applied Anthropology (René Descartes University – Paris V). The aim is to gain a better understanding of the cause(s) of this phenomenon in order to issue appropriate safety recommendations to reduce or eliminate this risk.

There have been several reported accidents and incidents that demonstrate that crews throughout the airline industry continue to attempt take-offs using incorrect take-off performance references (see Appendix B). In the occurrences identified in this report, the procedural defences that were in place did not function effectively and, on several occasions, this has resulted in substantial aircraft damage and loss of life. The frequency of occurrences shows that the risk of crews using incorrect take-off performance references remains high because the cockpit procedural and technical safety defences to prevent these errors have been either inadequate or absent.

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5 TSB investigation report A04H0004.

Analysis

The aircraft was serviceable for the flight and there were no environmental factors that were considered contributory. The analysis will therefore focus on the safety defences that were not effective in preventing the crew from attempting to take off using incorrect take-off performance references.

During the initial performance calculation, an error in the weight of fuel on board (FOB) for take-off was introduced. Therefore, the performance data generated was not correct. This resulted in the use of a lower-than-required thrust setting for take-off, V speeds that were inappropriate for the weight of the aircraft, and less-than-optimum performance and handling characteristics.

The turn-around time scheduled for the flight in CYEG was 45 minutes. During the course of a normal day, flight crews expect to have to deal with unforeseen or changing circumstances. The requirement to power down the aircraft on arrival and the EFB power source anomalies were particularly significant. In this case, the situation created an increased workload, particularly for the captain, and disrupted the normal procedural flow. While readying the aircraft for departure, both crew members deviated from SOPs. Whenever there is a deviation from normal procedures, there is more vulnerability to errors. Other non-standard events that would have added to the crew's overall workload management were the defective laptop cord, the absent flight service director, the overflowing coffee maker, the late change to departure runway, communication difficulties with ATC, and the later-than-scheduled gate departure.

SOPs are the primary safety defence to ensure that there is a correct, standard, and safe outcome for each phase of flight. To achieve this, the procedures must be sufficiently robust to withstand the daily challenges that crews face during normal operations. SOPs must be effective in circumstances where the crew is working under pressure, interrupted or distracted, facing non-standard situations, and in periods of high workload. Consequently, there must be human performance considerations during the design, development, and use of these critical defences. In this occurrence, the procedures in place failed to ensure that correct generation and use of take-off performance data occurred.

SOPs required the PNF to calculate the take-off performance data and the PF to verify the data before transcribing the data to the operational flight plan. These data could then be entered into the FMS. However, on this day, this was not done because both pilots deviated from SOPs and the PF calculated the take-off data.

Had the verification of the preliminary performance calculations been accomplished correctly, the discrepancy likely would have been identified at this point. The FOB field would have indicated 3700 kg instead of 10 200 kg and the estimated take-off weight (ETOW) field would have indicated 41 700 kg instead of the operational flight plan ETOW of 47 780 kg.

Although the SOPs required that the crew transcribe the EFB performance generated data to the operational flight plan, there was no specific location on the operational flight plan to transcribe the take-off performance figures. Therefore, the crew wrote them down on the top right corner of the page. Since the planned figures were located in the opposite corner, at the bottom left of that same page, it was difficult to compare the calculated performance figures and the planned figures. Had there been a specific area, adjacent to the planned figures, to transcribe the calculated performance data, the discrepancy between the planned take-off weight and the take-off weight used for generating the performance figures would have been easier to identify. It is more likely that the six-ton difference between the planned and calculated take-off weight would have caught the attention of the crew.

The fuel check was then completed. No discrepancies were noted since, by that time, the aircraft had been refuelled and the fuel gauge indication of 10.2 tons matched the operational flight plan required fuel of 10.15 tons. There were no specific requirements to verify the actual FOB against the FOB entry on the EFB take-off page during the fuel check procedure or the pre-flight procedure.

In this occurrence, the crew took off using incorrect take-off performance references. This was a result of a combination of the crew deviating from SOPs and the operational flight plan form design that prevented easy identification of discrepancies. The procedural defences that were in place did not function effectively and this could have resulted in substantial aircraft damage and loss of life.

Findings as to Causes and Contributing Factors

1. The normal flow of activities to prepare for the outgoing flight was interrupted, and the flight crew deviated from the standard operating procedures (SOPs) while readying the aircraft for departure.

2. An incorrect aircraft weight was used to calculate take-off performance data. This error was not detected, and resulted in the crew conducting the take-off with lower-than-required thrust and speed references.

3. There is no area on the operational flight plan for transcribing calculated performance data. This prevented easy identification of the take-off weight discrepancy.

Other Finding

1. A take-off performance monitoring system could have provided the crew with an accurate and timely indication of inadequate take-off performance.

Safety Action Taken

On 03 August 2007, the TSB issued Aviation Safety Advisory A06A0096-D1-A1 (*Use of Incorrect Take-Off References*) to Transport Canada (TC). The Aviation Safety Advisory informed TC of the Paris-Orly 10 December 2006 accident, and indicated that TC may wish to coordinate its efforts with those of the Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile (BEA) to accelerate safety action to mitigate the risk of crews using incorrect take-off data references.

On 21 December 2007, TC responded stating that it is continuing to work towards realizing the intent of TSB Aviation Safety Recommendation A06-07. A team of participants from diverse branches of TC and from the National Research Council (NRC) have met and agreed to a project work plan.

Through the International Air Transport Association (IATA) Safety Group, Air Canada has engaged the manufacturers to develop automated flight management system (FMS) take-off data entry gross error checking capabilities.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 31 January 2008.

*Visit the Transportation Safety Board's Web site (**www.tsb.gc.ca**) for information about the Transportation Safety Board and its products and services. There you will also find links to other safety organizations and related sites.*

Appendix A – Operational Flight Plan

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QU YEGRJQK
.YYZOAAC 121430
FUEL ADJUSTED 1 PERCENT ABOVE AVG CONSUMPTION FIN 311

FP 1156/12 E190 311 C-FHIU C10  CAPT [redacted]

CYEG/30 1550Z CYEG2 RYLEY DCT DALDE DCT 49N090W DCT SSM J588
TIBUD J525 YMS MANS3 CYYZ/06L

ALTN CYOW  G/C 1453

TO          EET   ET/AT  F/L  M/T  T/T  DST  TAS  TDV  WIND   COMP  TR  MFOB

RYLEY       0009../..    CLB             49       P07  23041        38  8.46

T O C       0034.../..   370            194       P05  23047        40  7.31

DALDE       0100../..    370            215  447  P01  25050  P035  40  6.40

49N090W     0158../..    370  103  111  468  451  P02  31028  P034  40  4.47

SSM         0233../..    370  125  122  277  453  P05  27037  P029  49  3.34

JOFFS       0246../..    390            104  447  P06  26057  P042  50  2.92

TIBUD       0249../..    390             26  447  P06  26061  P048  50  2.82

T O D       0255.../..   390             43  449  P06  26068  P022  49  2.65

CYYZ        0318../..    DSC            118                         49  2.36

                         TTL DST 1494 TMP P04   CMP P029

BURN | FIT  ALTN | CF   ATC  | TF   ELW
6.68 | 1.00 1.36 | 0.28 0.70 | 0.13 41.09

ALTN CYOW
CYYZ LEST7 GOPEV DCT LANRK CAPTL6 CYOW

TO          EET   ETA    F/L  DST TAS TDV COMP TR BURN  MFOB

CYOW        0040 .....  290  232 367 P13 P017 49 1.36  1.00
INFO
CYQG        0039 .....  200  183 327 P15 M016 49 1.23  1.00

PLANNED          ACTUAL         MAX          ACTUAL          SKED

PAX        82    ....81..                    OUT 1000        0950

BLOCK   10.15    ..10.27                     OFF 1011    B/B 0340

EZFW    37.75    ..37.6.        40.66        ON  1531    SKD 0340

ETOW    47.78    ..47.6.        50.69        IN  1538        1530

EZFW CORR                                    FOB 3.5

MACGTOW          ........UNITS

MACEZFW          .23.4.UNITS

OUT 00 OFF 11  FIN 311 FOB 10.27 00 LB/KG  UPLIFT 8760 LTR/GAL A/B
```

EFB calculated performance data

Planned

Appendix B – Take-off Performance Incident/Accident Occurrences

Date	Aircraft Type	Registration	Persons on Board	Location	Remarks
2007.03.28	Airbus A340	F-GLZP	n/a	Paris Charles de Gaulle International Airport, France	• Just before take-off, the crew decided not to use reduced thrust due to a tail wind of 5 knots. While inserting new data, an error was made (131, 131, 159 instead of 131, 151, 159). • The pilot flying delayed rotation. • Part of BEA's data insertion error study.
2006.12.10	Boeing 747-400	F-HLOV	578	Paris-Orly, France	• The take-off performance calculations were completed using the zero fuel weight (ZFW) instead of the take-off weight (TOW). The crew attempted take-off with less than the required thrust and rotation speed. • The aircraft suffered a tail strike at take-off. • The aircraft suffered damage to the lower aft fuselage. • No injuries to all 578 persons on board. • Part of BEA's data insertion error study.
2006.07.12	Embraer 190	C-FHIU	86	Edmonton, Alberta, Canada	• The crew did not take into account the fuel uplifted during turn-around. The take-off performance calculations were completed using a weight 6000 kg below the take-off weight, resulting in the crew taking off with less than the required thrust and rotation speed. • No injuries to persons on board. • Part of BEA's data insertion error study.

Date	Aircraft Type	Registration	Persons on Board	Location	Remarks
2005.08.24	Airbus A340-300	LN-RKF	n/a	Shanghai, China	• The take-off performance calculations were completed using the ZFW instead of the TOW. • Part of BEA's data insertion error study.
2004.10.14	Boeing 747-244SF	9G-MKJ	7	Halifax, Nova Scotia, Canada	• The crew attempted take-off with less than the required thrust and rotation speed. • The aircraft suffered a tail strike at take-off, followed by collision with terrain. • The aircraft was destroyed. • All seven crew members suffered fatal injuries. • Part of BEA's data insertion error study.
2004.07.14	Airbus A340-313	F-GLZR	n/a	Paris Charles de Gaulle International Airport, France	• The take-off performance calculations were completed using a weight 100 tons below the take-off weight. The crew attempted take-off with less than the required thrust and rotation speed. • The aircraft suffered a tail strike at take-off. • The aircraft suffered major damage to the lower aft fuselage. • No injuries to persons on board. • Part of BEA's data insertion error study.

Date	Aircraft Type	Registration	Persons on Board	Location	Remarks
2003.09.04	Airbus A321	OY-KBK	n/a	Oslo, Norway	• Because of equipment problems on the aircraft, the take-off performance calculations were completed by Operations. A weight of 60 tons was used instead of 76.4 tons. • This resulted in the crew attempting take-off with too low V speeds (29 knots). The aircraft felt heavy on take-off. • No damage to the aircraft and no injuries to persons on board. • Part of BEA’s data insertion error study.
2003.03.12	Boeing 747-412	9V-SMT	389	Auckland, New Zealand	• The take-off performance calculations were completed using a weight 100 tons below the take-off weight. The crew attempted take-off with less than the required thrust and rotation speed. • The aircraft suffered a tail strike at take-off. • The aircraft suffered damage to the lower aft fuselage. • No injuries to persons on board. • Part of BEA’s data insertion error study.
2003.03.11	Boeing 747-300	ZS-SAJ	157	Johannesburg, South Africa	• The take-off performance calculations were completed using the ZFW instead of the TOW (difference of 124 tons). The crew attempted take-off with lower-than-required rotation speed. • The aircraft suffered a tail strike at take-off. • The aircraft suffered damage to the lower aft fuselage. • No injuries to persons on board. • Part of BEA’s data insertion error study.

Date	Aircraft Type	Registration	Persons on Board	Location	Remarks
2002.06.14	Airbus A330-343	CG-HLM	266	Frankfurt, Germany	• The crew initiated rotation 24 knots before the calculated Vr of 157 knots. • The aircraft suffered a tail strike at take-off. • The aircraft suffered substantial damage to the lower aft fuselage. • No injuries to persons on board • Part of BEA's data insertion error study.
2001.12.28	Boeing 747-128	N3203Y	3	Anchorage, Alaska, United States	• The crew did not take into account the fuel uplifted during turn-around. The take-off performance calculations were completed using a weight 100 000 pounds below the take-off weight. • The aircraft suffered a tail strike at take-off. • The aircraft suffered substantial damage to the lower aft fuselage. • No injuries to persons on board. • Part of BEA's data insertion error study.
1999.08.24	Boeing 767-383	OY-KDN	191	Copenhagen, Denmark	• The take-off performance calculations were completed using the ZFW instead of the TOW (difference of 63 300 kg). The crew attempted take-off with too low V speeds (33 knots) and take-off was rejected at a speed of 158 knots, when the aircraft would not get airborne. • The aircraft suffered a tail strike at take-off. • The aircraft suffered minor damage. • No injuries to persons on board. • Part of BEA's data insertion error study.

Date	Aircraft Type	Registration	Persons on Board	Location	Remarks
1990.01.16	Boeing 757-200	N505UA	176	New York, New York, United States	• Take-off performance calculations were completed using the Boeing 767 data instead of the Boeing 757 data. This resulted in the crew attempting take-off with too low V speeds (30 knots). • The aircraft suffered a tail strike at take-off. • The aircraft suffered substantial damage. • No injuries to persons on board. • Part of BEA's data insertion error study.

Appendix C – Glossary

AC	Advisory Circular
ACARS	Aircraft Communication Addressing and Reporting System
agl	above ground level
asl	above sea level
ASR	Air Safety Report
ATC	air traffic control
BEA	Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation Civile
CASS	Commercial Air Service Standards
CBAAC	Commercial and Business Aviation Advisory Circular
CYEG	Edmonton International Airport, Ontario
CYYZ	Toronto/Lester B. Pearson International Airport, Ontario
DGAC	Direction Générale de l'Aviation Civile
EFB	electronic flight bag
ETOW	estimated take-off weight
EZFW	estimated zero fuel weight
FAA	Federal Aviation Administration
FMS	flight management system
FOB	fuel on board
FSD	flight service director
IATA	International Air Transport Association
kg	kilograms
NRC	National Research Council
N1	thrust
PED	portable electronic device
PF	pilot flying
PNF	pilot not flying
sm	statute miles
SOPs	standard operating procedures
SPDA	secondary power distribution assembly
STOC	Station Operation Control
TC	Transport Canada
TOPM	Take-off Performance Monitoring (system)
TOW	take-off weight
TSB	Transportation Safety Board of Canada
Vfs	flaps up speed
Vr	rotation speed
V1	decision speed
V2	take-off safety speed
ZFW	zero fuel weight
°C	degrees Celsius