



Submission to the
National Transportation Safety Board
for the
Continental Airlines 737-500 N18611
Runway Excursion During Take-Off
At
Denver International Airport
December 20, 2008

The Boeing Company
23 February 2010

INTRODUCTION

On December 20, 2008, at 1818 Mountain Standard Time (MST), Continental Airlines (CAL) Flight 1404, a Boeing 737-500 (registration N18611), equipped with CFM56-3B1 engines, departed the left side of runway 34R during takeoff from Denver International Airport (DEN). The scheduled, domestic passenger flight, operated under the provisions of Title 14 CFR Part 121, was en route to George Bush Intercontinental Airport (IAH), Houston, Texas. There were 37 injuries among the passengers and crew, and no fatalities. The airplane was substantially damaged and experienced a post-crash fire. The weather observation in effect at the time of the accident was reported to be winds at 290 and 24 knots (kt) with gusts to 32 kt, visibility of 10 miles, a few clouds at 4000 feet and scattered clouds at 10,000 feet. The temperature was reported as -4 degrees Celsius. The tower reported winds of 270° and 27 kt with the take-off clearance.¹

Submission Abstract

- The Boeing Company, as the airplane's manufacturer, is acting as a technical and operational advisor to the National Transportation Safety Board (NTSB) in this investigation.
- The conclusions presented in this submission are based on factual information, Boeing's expertise, the use of analytical tools, and a methodical investigation process.
- Based on the factual evidence gathered during this investigation, Boeing believes the most likely cause of the airplane departing the runway is the lack of sufficient rudder pedal inputs during the take-off roll to maintain directional control in the gusty crosswind conditions.
- The investigation did not reveal any anomalies with the airplane or its systems.

¹ NTSB- *Airplane Performance Study, Specialist's Report of Investigation*, no date, page 1



BOEING ASSISTANCE WITH THIS INVESTIGATION

The NTSB is leading the investigation into the Continental Airlines 737-500 accident. Assisting the NTSB in their investigation are the Federal Aviation Administration (FAA), Continental Airlines, ALPA (Air Line Pilots Association), NATCA (National Air Traffic Controllers Association), DIA- OPS (Denver International Airport- Operations), CFM, Boeing and other designated parties.

As the manufacturer of the 737-500 airplane, Boeing's specific role in this investigation has been to provide technical information regarding the airplane's design and operation to assist the NTSB.

The NTSB requested that all parties submit proposed findings to be drawn from the evidence revealed during the course of the investigation. Boeing has responded to the NTSB's request with this document, which:

- Provides an assessment of the evidence and other pertinent data.
- Identifies knowledge gained from the investigation.
- Identifies conclusions and a recommendation supported by the knowledge gained from the investigation.



AIRPLANE HISTORY

The aircraft was manufactured by Boeing in Seattle, Washington in June, 1994. The aircraft had 40,541 total hours and 21,511 total cycles as of the previous landing at Denver International Airport and prior to the time of the accident on December 20, 2008. The aircraft was equipped with two CFM56-3B1 engines and a Honeywell Auxiliary Power Unit (GTCP85-129H).²

Continental Airlines completed installation of winglets, via Supplemental Type Certificate ST01219SE³, on November 29, 2008⁴.

²NTSB *Aircraft Maintenance Records Factual Report*, dated 30 June 2009, page 4.

³ NTSB *Aircraft Maintenance Records Factual Report- Attachment B, Supplemental Type Certificates*, no date, pages 1-10.

⁴ NTSB *Aircraft Maintenance Records Factual Report- Attachment G, Major Repairs & Alterations*, no date, page 2.

EVIDENCE ASSESSMENT

The following Boeing assessment of the evidence is based upon observations of the airplane and accident site, post-accident examination of airplane systems and components, flight data recorder (FDR) data, full-motion simulator results (simulator was back-driven by the FDR data) and flight crew interview data.

Summary of Ground Track

The accident airplane, properly configured, was positioned for takeoff. The airplane's ground track remained down the runway centerline until it reached a speed of 90 knots, at which time the heading and ground track began rapidly increasing left. Within seconds of deviating from the runway centerline, the airplane departed the runway and came to rest in a ravine.

Winds

The ATIS weather observation in effect at the time of the accident was reported to be winds at 290° and 24 knots (kt) with gusts to 32 kt, visibility of 10 miles, a few clouds at 4000 feet and scattered clouds at 10,000 feet. The temperature was reported as -4 degrees Celsius. The tower reported winds of 270° and 27 kt with the take-off clearance⁵.

Because winds are considered a factor in this accident, efforts were made to extract the winds from the FDR data that were present during the accident sequence. Two independent studies were performed, one by the NTSB and one by Boeing.

The NTSB study estimated that winds for the accident varied between 30 kt and 45 kt out of the west, almost a direct crosswind for Denver's Runway 34R. A peak gust of 45 kt was extracted at about the same time the 24° airplane nose right (ANR) rudder input was returning to a near neutral position and about 1.5 seconds after the first recorded tire skid marks. This is in comparison to the Low Level Wind shear Alert System (LLWAS) at the Denver Airport which recorded a ten-second average wind of 40 kt approximately two minutes prior to the accident and 34 kt around the time of the accident.

Similarly, Boeing estimated the accident winds as gusting out of the west at 25 kt to 40 kt. The results aligned well with the LLWAS sensor data.⁶ (Details of each of these studies are included in the NTSB Airplane Performance Study.) Irrespective of the exact winds that were present during Continental Flight 1404's take-off attempt, FDR data show that the airplane was capable of tracking the runway centerline⁷, with appropriate rudder pedal inputs.

⁵ NTSB Airplane Performance Study, Specialist's Report of Investigation, no date, page 1.

⁶ NTSB Airplane Performance Study, Specialist's Report of Investigation, no date, page 5 and 7.

⁷ NTSB Airplane Performance Study, Specialist's Report of Investigation, no date, page 3.

Directional Control - FDR Data Summary

As plots 1, 2, 3 and 4⁸ of the FDR data indicate, the airplane initially tracked the runway centerline during the take-off roll while rudder pedal input was applied. During the takeoff roll, varying amounts of right rudder pedal were applied to counter the large and gusty crosswind from the left. Later in the takeoff roll, the rudder pedal input was removed, and at this point the aircraft deviated to the left and departed the runway. The FDR data shows that the aircraft did not depart centerline until the rudder pedal input was removed.

On two different visits to the accident site by the investigation party members, the directional control system was inspected and documented. No abnormalities or restrictions were noted. Several key components were removed from the airplane and tested at their manufacturer's test facilities or at Boeing test facilities with the NTSB and other party members in attendance. No anomalies were noted with any of the components tested.⁹

737-500 Crosswind Certification

Boeing demonstrated a takeoff in a 35 kt crosswind during certification of the 737-300. Similarly, a takeoff in a 22 kt crosswind was demonstrated during certification of the 737-500 with winglets. These crosswind values are not considered limiting.¹⁰ Through analysis, Boeing has shown that the 737-500 is controllable in a 40 kt crosswind on a dry runway. The analysis also shows that there is additional control available for crosswinds greater than 40 kts. Boeing evaluation of the 737-500 showed that the winglets have a negligible effect on airplane crosswind performance.¹¹ Therefore, the 737-500 with winglets is controllable in crosswinds greater than 40 kt on a dry runway. As specified in the Code of Federal Regulations (CFR), Boeing is not required and does not set a crosswind limit for its airplanes.

Continental Airlines Simulators

During the course of the investigation, it was noted that the atmospheric model used in the Continental Airlines B-737-500 Full-Flight Simulator (FFS) does not include crosswind gusts below an altitude of 50 feet.¹²

⁸ NTSB *Flight Data Recorder- 10, Specialist's Factual Report*, dated May 8, 2009, pages 10-5 thru 10-8.

⁹ NTSB *Systems Group Chairman's Factual Report*, dated 6-30-2009, several sections throughout the document.

¹⁰ NTSB *Airplane Performance Study, Specialist's Report of Investigation*, no date, page 8.

¹¹ NTSB *Airplane Performance Study- Specialist's Report of Investigation*, no date, page 5.

¹² NTSB *Airplane Performance Study, Specialist's Report of Investigation*, no date, page 8.

KNOWLEDGE GAINED DURING THE INVESTIGATION (Findings)

The following summarizes knowledge gained that is pertinent to drawing conclusions:

- Low Level Wind Shear Alert System (LLWAS) and Automatic Terminal Information Service (ATIS) data noted large magnitude steady crosswinds with gusts.
- The crosswind gust levels were likely larger than was reported to the crew and that the crew had experienced during training.
- The Flight Data Recorder (FDR) data show the rudder was effective at maintaining the aircraft on the runway centerline.
- The FDR data show that the airplane did not depart the runway centerline, and subsequently the runway, until rudder pedal input was removed.
- The investigation did not reveal any anomalies with the airplane or its systems.
- The airplane was being operated within its certified operating envelope.
- Winglets have a negligible effect on 737-500 crosswind performance.
- Crosswind gusts are not currently being simulated in the Continental Airlines training simulators below an altitude of 50 feet.

CONCLUSION

Boeing believes the most likely cause of the airplane departing the runway is the lack of sufficient rudder pedal inputs during the take-off roll to maintain directional control in the gusty crosswind conditions.

RECOMMENDATION

Boeing makes the following recommendation based on the knowledge gained:

- The industry should consider implementing simulator training curriculums that use realistic strong and gusty crosswinds during take-off and landing scenarios.