Submission of the
Air Line Pilots Association, International
to the
National Transportation Safety Board
Regarding the Accident Involving

Continental Flight 1404

B737-500

DCA09MA021

Denver, Colorado

December 20, 2008

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Executive Summary

On December 20, 2008, at 1818 Mountain Standard Time (MST), a Boeing 737-524, Continental Airlines flight 1404, departed the left side of runway 34R during takeoff from Denver International Airport (DEN). The airplane was substantially damaged and experienced a post-crash fire. There were 37 injuries but no fatalities among the 2 flight crewmembers, 3 flight attendants, and 110 passengers.

The purpose of this analysis is to identify the specific chain of events that led to the accident and make recommendations to prevent a future occurrence. ALPA's analysis identified the following safety issues: simulator fidelity in modeling crosswind operations; inadequacies within the airline's training and guidance material; FAA Air Traffic Control's (ATC) methodology for providing wind information to flight crews; the lack of manufacturer's guidance for crosswind takeoff and landing procedures; and the absence of specific crosswind limitations provided by manufacturers to operators.

ALPA believes that the aviation industry, not just Continental Airlines, needs to reevaluate simulator Fidelity to ensure that the simulators can properly model both crosswind and gusty wind conditions. Following these improvements the FAA in conjunction with industry should ensure that crosswind and gusty winds are incorporated into the training syllabuses at the airlines, up to the operational limitations of the aircraft, which need to be established.

The ATC facility at Denver has one of the most sophisticated wind sensing systems in the United States, but only a small portion of that information is available to each controller at their operating station. Controllers should be provided with additional information and guidance from the FAA, specifically during rapidly changing wind events, which would enable them to provide a more accurate representation of the spectrum of varying wind conditions that may be encountered by departing and arriving flights. Controllers should also be given better guidance on how to use wind sensors that are most appropriate for the runway configuration. This did not occur prior to the accident involving flight 1404. ALPA also believes that while the system may be one of the best in the country it is still missing key sensors that would have provided ATC a better picture of the wind event on December 20, 2008, specifically in the Northwest quadrant of the airport.

The aircraft manufacturer does not provide specific crosswind limitation for the 737-500, or any other models that the airline operates. More importantly though, the aircraft manufacturer is not required to do so by the Federal Aviation Administration (FAA). ALPA believes that the FAA should require aircraft manufacturers to set a limitation for maximum crosswind; this would result in making these limitations mandatory for airline operations.

ALPA understands that there also were human performance elements to this accident. Although both the Captain and First Officer thought that the Captain had full right rudder, the data shows that was not the case, specifically on the second rudder application. To fully understand the decisions that the flight crew made that day, the analysis must look at the event in the context of the perceptions on which the crew based their decisions.

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1.0 Factual Information

1.1 History of Flight

On December 20, 2008, at 1818 MST, a Boeing 737-524, N18611, operated by Continental Airlines Inc. as flight 1404, 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 enroute to George Bush Intercontinental Airport (IAH), Houston, Texas. The airplane was substantially damaged and experienced a post-crash fire. There were 37 injuries but no fatalities among the 2 flight crewmembers, 3 flight attendants, and 110 passengers.

According to the flight crew, they arrived at the airport about 1700 MST, and proceeded to conduct pre-flight activities in preparation for the flight to IAH.

During the pre-flight activities, the flight crew obtained pertinent weather and air traffic control information, to include the current Automated Terminal Information System (ATIS) and pre-departure clearance (PDC). Prior to push back from the gate, the flight crew also received three ACCULOAD[1] information sheets pertaining to the flight, each for a different runway to include runway 34R.

After the main cabin door was closed, the First Officer (FO) contacted ramp control and received a clearance to push back from the gate and plan for a west taxi. The flight pushed back at 1801 MST, and upon visually observing ice and snow on the ramp, the Captain elected to start both engines and utilize engine and wing anti-ice systems for the taxi to runway 34R.

During the taxi to runway 34R, the Captain did not observe any buffeting of the airplane from wind.[2]

As the airplane approached runway 34R, the flight crew performed the before takeoff checklist and contacted the tower. A Beech 1900D was on the runway ahead of them, awaiting a takeoff clearance. After the Beech 1900D departed, the tower cleared flight 1404 into position and hold on the runway, which appeared to be clear of snow and ice. As the flight crew waited for takeoff clearance, about 2-3 minutes, they observed that all of the runway lights and all of the airplane's lights were on and runway visibility was excellent.

While waiting for takeoff clearance, the Captain stated, "looks like you got some wind out here…" followed by, "oh yeah look at those clouds moving."[3]

[1] Continental Airlines uses a computer based weight and balance system called ACCULOAD. It is an integral part of the Flight Operations Management System (FOMS) and is used to generate the Pilot Weight Manifest (PWM). ACCULOAD uses input from the dispatcher concerning MEL-CDL and weather restrictions, the information in FOMS (weather), as well as inputs from a qualified load planner (such as cargo, fuel, and customers) when computing weight and balance data. Weight adjustment codes can also be entered if necessary. ACCULOAD ensures that all performance and aircraft limitations are not exceeded. A PWM will only be generated if the data is within the acceptable limits.

[2] Operations and Human Performance Factual Report, Page 3

[3] Cockpit Voice Recorder Factual Report, Page 12-36

At 1817:26 MST, the tower informed the flight crew that winds were 270 degrees at 27 knots and to turn right to a heading of 020 degrees after takeoff, and subsequently cleared them for takeoff. The First Officer replied to the controller, "heading 020 cleared for takeoff runway 34R..." The Captain, who was the pilot flying (PF), then replied, "left cross wind twenty ah seven knots."[4]

After applying thrust, the Captain observed a difference in the thrust being generated by the two engines; however, the engines soon began to match each other as they spooled up. The Captain then pressed the TOGA button and called out, "check power" and the engines spooled up to their desired setting of 90.9% N_1. The First Officer confirmed and announced that the thrust was set at 90.9%.

After the thrust was set, the Captain applied a left control wheel correction and used right rudder to keep the airplane aligned with the runway centerline. He recalled that it felt at first like a "normal crosswind takeoff."[5]

As the airplane began to accelerate down the runway, it suddenly yawed to the left, as if hit by a "massive gust of wind,"[6] or as if the tires had hit a patch of ice and lost traction.[7] The Captain applied almost full right rudder to counteract the motion, but the airplane continue to the left. The First Officer recalled that as airspeed was increasing from 87 to 90 knots he looked up and observed the airplane drifting left of the runway centerline. He thought the Captain was correcting back to the right, but the airplane suddenly yawed 30 to 45 degrees to the left. It appeared to the First Officer as if there was "zero directional control."[8] He recalled feeling the rudder pedals with his feet and he believed the Captain was applying full right rudder.[9]

As the airplane continued to the left, the Captain observed that he was facing the edge lights on the left side of the runway, and believed that the airplane was going to exit the left side of the runway. As "a last resort," he reached down with his left hand and grabbed the nose wheel tiller for a second or two, in an attempt to steer the airplane back onto the runway.

As the airplane departed the left side of the runway edge, the Captain recalled using right control wheel input to keep the wings level, because he thought the ground next to the runway sloped down and he feared that the aft end of the fuselage would slide down that incline and cause the airplane to "tumble on its side." After the airplane completely exited the runway, the Captain stated, "reject" several times, reduced the thrust levers to idle, and attempted to deploy the thrust reversers; however, was unable to deploy them "because the ride was very rough."[10]

The airplane continued through a grassy area for about 1,100 feet, then crossed a taxiway, and continued for an additional 70 feet, where it left the ground due to a steep elevation drop off. The

[4] Cockpit Voice Recorder Factual Report, Page 12-36
[5] Operations and Human Performance Factual Report, Page 4
[6] Operations and Human Performance Factual Report, Page 4
[7] Operations and Human Performance Factual Report, Page 4
[8] Operations and Human Performance Factual Report, Page 4
[9] Operations and Human Performance Factual Report, Page 4
[10] Operations and Human Performance Factual Report, Page 4

airplane touched down again in a grassy area, about 168 feet beyond the drop off, and impacted upward sloping terrain of an access road. The airplane crossed the access road, and continued an additional 250 feet, where it came to rest. Subsequently, a fire ensued on the right side of the aircraft.

After the airplane came to rest, neither the Captain, nor the First Officer recalled hearing any engine sounds, and observed that the flight deck was completely dark. As the First Officer stood up from his seat, a deadheading crewmember knocked on the cockpit door and the First Officer opened it. About this time, the Captain was trying to get out of his seat as well, but a dislodged flight crew bag was blocking his path. The First Officer moved the bag, and he and the deadheading crewmember assisted the Captain out of his seat, and they all evacuated the airplane.

2.0 Analysis

2.1 Meteorological Factors and Wind Calculations

The takeoff of flight 1404, based on the meteorological data, appeared to have taken place during a katabatic wind[11] event that was coming across the Denver International Airport. This downsloping warming wind is quite common in the Front Range during the winter season.[12]

The data also showed a wind speed increase from the time the ATIS was issued until the accident aircraft started to depart. The ATIS obtained by the crew prior to push back from the gate indicated the wind was 270 at 11 knots.[13]

The wind report provided to flight 1404 in the takeoff clearance was 270 at 27 knots which was from a wind sensor located approximately 10,000 feet north and 3,400 feet east of the runway 34R threshold. This resulted in the airplane encountering an almost direct crosswind conditions.

The wind sensor closest to flight 1404 during the initial takeoff was reporting a two-minute average of winds 280 at 34 knots gusting to 40 knots.[14] Had this wind information been provided to the flight crew of flight 1404, ALPA believes the Captain may have reevaluated his decision to depart on Runway 34R, which could have been to request a more suitable runway (runway with less of a crosswind component) or delay their departure.

The Airplane Performance Study extracted winds from the flight data recorder and AMASS[15] information showing winds varied between 30 to 45 knots out of the west, almost a direct crosswind for flight 1404, and well in excess of the winds provided to the crew with their takeoff clearance.[16] In addition, when variability for drift angle error was taken into consideration, the peak wind could have been as high as 51 knots. Although no explicit crosswind limitations are provided for the 737-500, these winds exceeded all the demonstrated crosswind values published by Boeing.[17]

Boeing, on the other hand, concluded the winds were “gusting out of the west at 25 kt to 40 kt”. However, the Boeing does not use the methodology prescribed in the study. The study was designed to “extract the winds present during the accident sequence using both measured FDR and predicted airplane performance data.” Boeing produced two models and took an average of the two to develop their wind calculations. Boeing then took this averaged data and further modified it to align with the results of the LLWAS data.[18] This contradicts the purpose of the study which was to calculate the winds

[11] Downslope winds flowing from high elevations of mountains, plateaus, and hills down their slopes to the valleys or planes below.
[12] Meteorological Factual Report Addendum 1, Pages 28-33
[13] Operations and Human Performance Factual Report, Page 3
[14] Meteorological Factual Report Table 4, Page 10-11
[15] Airport Movement Area Safety System - radar that track aircraft movements on or near the airport surface
[16] Airplane Performance Study, Page 5
[17] Airplane Performance Study, Page 8
[18] Airplane Performance Study, Page 6

at the time of the accident. If the modifying effect of LLWAS winds in the Boeing analysis is removed, the calculated peak wind at the time in question was similar to the results obtained by the NTSB.

Additionally, due to the rapidly changing and unique terrain features surrounding runway 34R, it is possible that the installation of additional wind sensors in the northwest quadrant of the airport would have detected the strong winds prior to flight 1404’s departure.

2.2 NTSB Performance Modeling

The NTSB Performance group work was based on an amalgamation of two models, the 737-200 and 737-300. Boeing did not provide the NTSB with a 737-500 performance model, which not only delayed the performance group's work, but also introduced errors into the performance calculations. While these calculations ultimately were corrected, it was not until the late stages of the investigation. The issue becomes that an NTSB investigation is based on being able to independently verify the performance of the aircraft. Not having the exact performance model and relying on the manufacturer to provide guidance on manipulating the other models takes away from the NTSB's ability to independently evaluate this data. An additional concern is that the majority of the Performance group work was accomplished only between the NTSB and Boeing. No other parties were included in the development of the study and the subsequent report.

2.3 Airplane Performance

Examination of the FDR data plots beginning at time 1817:41 MST show that the initial phase of the takeoff was routine for the gusty and crosswind conditions. As the thrust levers were initially advanced to approximately 12°, Engine 2 (the right side engine) began to spool up slightly ahead of Engine 1. As both engines approached 40% N_1, the engine thrust levers were advanced to the takeoff power position and Engine 1 then began to spool up quicker than Engine 2. Both engines eventually stabilized at approximately 90% N_1. The recorded level of engine asymmetry during spool up was somewhat unusual and added to the pilot’s workload as he would normally be focused on “hunting” for the appropriate amount of rudder application to counter the wind conditions. Varying or cyclic rudder applications are normal as the pilot searches for the proper rudder input to maintain centerline in constantly changing conditions. Historical data has shown that the time between rudder pedal cyclic extensions is usually about 4.5 seconds in high crosswind situations.[19] The time between the rudder peaks of the accident aircraft was 4 seconds thus showing that the swiftness of the inputs was the same or slightly faster than other takeoffs under high crosswind conditions.

As the aircraft accelerated through 70 knots airspeed, it still had a 3 degree drift angle as the right rudder pedal went to a near full displacement by 1818:08 MST. At about 1818:03 MST, as the engines stabilized at about 90% N_1, the aircraft began a right drift angle (left track) indicative of weathervaning into the left crosswind. At about the same time there was right rudder control accompanied by left aileron input to counter the crosswind effect.

[19] Operations and Human Performance Factual Report Attachment 6, Page 2

The heading began to respond within 1 second of the first large rudder application as it shifted almost 1 degree to the right, at which point the pilot began to release the rudder. This would have led the pilot to believe that near full right rudder application was sufficient to manipulate the heading to counter the weathervaning effects of the wind while at the same time trying to maintain centerline. Of note, this heading shift was accompanied by an expected change in lateral acceleration, which can be felt by the flight crew. At or near 1818:11 MST, the heading began changing back to the left and the pilot had already begun a right rudder application to counter that change. However, upon application of the second rudder input, the heading or yawing moment did not change back to the right as was experienced in the first rudder application. As well, the pilot also did not "feel" any change. This would have been seen in the data as a shift in lateral acceleration as was experienced in the first rudder input. In fact, a mere one second after the second rudder input, the opposite lateral acceleration was felt and intensifying over the preceding next few seconds. (Note: Unfortunately, the 737-500 FDR does not record rudder pedal force as in many newer generation aircraft. This may have given a better understanding as to what force the pilot was applying.)

Sudden gusts of wind can sometimes be seen in other areas of the data such as the upwind wing rising causing a slight rolling motion. At 1818:10-11 MST, data shows the aircraft transition from a slight left bank to a slight right bank without an appreciable change in pilots control wheel inputs. Gusts can sometimes be seen by a sudden increase in airspeed. At 1818:11 MST, data shows an increase in airspeed beyond that indicated by the linear acceleration. Finally, the data does not show position of the aircraft accurately due to parameter fidelity, however, the Airplane Performance Study attempted to calculate relative position by integrating AMASS data as shown in the plots in Figure 1 and again in Figure 19 of the study. Figure 1 seems to show a tendency for the aircraft to drift to the right and Figure 19 shows at least some part of the aircraft nearly 20 feet right of centerline at 1818:10 MST and tracking further right.

As the pilot began inputting right rudder for the second time, the aircraft heading began tracking further left with a two degree heading change in approximately 2 seconds. It is also important to note that before the second rudder application was at its peak the aircraft began skidding. After applying the second rudder application, the pilot would have expected to have at least the same reaction as the previous rudder pedal input and get a commensurate change in heading back to the right. The yaw rate continued to the left. It is important to note that a peak wind of 45 knots was calculated by the NTSB Airplane Performance Study to occur immediately following the second rudder input. At 1818:14 MST the rudder input had cycled to near zero with the aircraft's heading continuing to the left. It is possible that the aircraft was exhibiting a skidding motion towards the right as the aircraft was continuing to weathervane left. According to his statement, the pilot grabbed the tiller as a last resort to keep the aircraft on the runway. The speed at which this event occurred combined with the feeling that the rudder was ineffective resulted in the pilot utilizing the only means left to maintain aircraft control, nose wheel steering.

There is one statement in the Airplane Performance Study that does not seem to be validated by any airplane performance data and in fact some data may refute the conclusion. The statement was "[i]rrespective of the winds that were present during Continental flight's 1404 takeoff attempt, select FDR shown that the airplane was capable of tracking the runway centerline."[20] This statement does not include an explanation as to what data it uses to prove the aircraft was capable of maintaining centerline. Even if the pilot elected to go against years of practice of using cyclic rudder inputs to maintain track and simply held full right rudder, the FDR data cannot prove whether the airplane would have remained on the runway or not.

The other aspect of the study that ALPA believes should not have been part of the Airplane Performance Study was Boeing's wind analysis. This analysis was accomplished by one party and could not be verified by the NTSB or other group members. As stated in the Meteorological Factors and Wind Calculations section above, the process that Boeing used to "modify" the winds were not in line with the study methodology.

2.4 Human Performance

According to the CVR, just prior to takeoff, the Captain and the First Officer comments revealed that they were aware the winds would be of a concern, but thought they would still be within the crosswind component guidelines specified in the 737 AFM for a crosswind takeoff.[21] Thus, the crew anticipated the crosswind and assumed they could safely control the aircraft by applying crosswind takeoff techniques, as trained.

As the aircraft began the takeoff roll the situation was relatively routine, however as the aircraft accelerated through approximately 70 knots, the Captain applied what he perceived to be full right rudder to counteract a very strong wind gust. Approximately 4 to 6 seconds later as the aircraft accelerated through 90 knots, the Captain applied again what he perceived to be full right rudder.[22] However, the aircraft did not respond to the second rudder application as the pilot expected. The aircraft continued its yaw to the left. The failure of the applied rudder to correct the left yaw, along with the visual perception that the aircraft was heading towards the left side of the runway led the Captain to readily and accurately conclude that his current actions were not working. With virtually no time to assess why the aircraft was not responding as expected, the Captain felt like he needed to react immediately to prevent the aircraft from departing the runway surface. Since his normal technique was not working as anticipated, and the edge of runway 34R was rapidly approaching, the Captain resorted to other options. As a last ditch effort he applied full right nose-wheel steering tiller to try to prevent the aircraft from departing the runway.[23] However, it became immediately apparent that this action would not prevent the aircraft from departing the runway.

When the Captain realized that he could not prevent the aircraft from leaving the runway surface, he continued to manipulate the flight controls in a manner so as to minimize the damage potential from departing the prepared surface. He went from trying to keep the aircraft on the runway to trying to keep

[20] Airplane Performance Study, Page 3
[21] CVR Factual Report, Page 37, time 1816:47 MST.
[22] Operations and Human Performance Factual Report, Page 4
[23] Operations and Human Performance Factual Report Attachment 1, Page 3.

the wings level in order to prevent the aircraft from sliding down the side of the embankment beyond the runway surface and possibly having the aircraft roll.[24]

2.5 Operational Factors

2.5.1 Crosswind Limitations & Procedures

Continental Airlines currently operates 6 variants of the 737 fleet-type: 737-300, 737-500, 737-700, 737-800, 737-900, and 737-900ER. All of these vary considerably in weight and length.

The Continental 737 Aircraft Flight Manual (AFM), Section 1, Limitations and Operating Parameters, lists a single set of crosswind guidelines used for all 737s. They are listed in a table called "Recommended Takeoff Crosswind Component Guidelines." A note precedes the table which states: "The crosswind guidelines presented below were derived through flight test data, engineering analysis, and piloted simulation evaluations. Therefore, the use of these guidelines should be based on the current weather conditions and pilot's ability and experience level." The crosswind component listed in the table for a dry runway is 33 knots.

The AFM crosswind component verbiage for takeoff and landing has changed several times over the last few years with the introduction of winglets on the various aircraft. Original verbiage before the introduction of the winglet aircraft simply stated that the maximum demonstrated crosswind was 35 knots. Boeing said that it has shown that the 737 is controllable in a 40 knot crosswind on a dry runway.[25] According to the Airplane Performance Study, Boeing states that the maximum demonstrated crosswind was 35 knots for the 737-300 (a model 11 feet 10 inches longer than accident aircraft and with the same size rudder, which would provide greater rudder authority). The Airplane Performance Study also states that Aero Tec (on behalf of Aviation Partners Boeing (APB), the manufacturer and installer of winglets installed on the accident aircraft) tested winglet affects during crosswind conditions up to a maximum demonstrated crosswind limit of only 22 knots for the 737-500W winglet aircraft. This number is not mentioned in the company's AFM for pilot reference. There is no discussion of gusty wind limits or the aircraft's capability to handle various gusty wind conditions in the company AFM.

Continental Airlines does conduct crosswind takeoff training at different wind velocities. However, a study into the fidelity of the simulators found that they can only simulate steady-state winds during the takeoff roll.[26] Current simulator programming restricts the use of gusts until the aircraft reaches 50 feet above the ground. Thus, simulator training for the takeoff roll portion of a takeoff in gusty crosswinds *is not possible*. ALPA is concerned that this simulator limitation actually results in "negative training" or a false sense of security inasmuch as pilots are always exposed to a less challenging weather phenomenon than is likely to be encountered in actual operations.

[24] Operations and Human Performance Factual Report Attachment 1, Page 3
[25] Airplane Performance Study, Page 8
[26] Analysis of the Simulation of "Wind Effects" in the Continental Airlines Inc. Thomsom (Link Miles) B737-500 Level D Full Flight Simulator, FAA ID 473

The NTSB Operations Group interviewed a number of line pilots and Continental Airlines Training Department pilots. They were asked how they applied the crosswind guidelines as listed in the AFM. There was no common answer. Some applied the 33 knot number as a limit to never exceed,[27] while some used it as a guideline to exceed depending on their experience level and the outside environment.[28] Some state that the guidelines applied to steady state winds while others thought it included gusts.[29]

Historical information provided by both Continental and United Airlines show that a line pilot rarely encounters a crosswind component in excess of 30 knots during takeoff. In fact, based on the numbers below, crosswind takeoffs in excess of 30 knots are so rare that in order to ensure pilots are successful in these weather conditions airlines must ensure that pilots are trained in a simulator with crosswinds in excess of 30 knots. The actual numbers are as follows:

Continental Airlines

Out of 940,000 takeoffs in all airplane types (except the 737-300), when crosswind component was measured 7 seconds after takeoff, only (62) 0.0066% encountered crosswind of 30 knots or greater. Out of 250,327 takeoffs in the 737-500, when crosswind component was measured 7 seconds after takeoff, (4) 0.00002% encountered a crosswind of 30 knots or greater.[30]

United Airlines

Takeoffs with a crosswind component greater than 30 knots were calculated at .041% system wide.[31]

2.5.2 Boeing 737-500 Handling Qualities

The NTSB Operations Group interviewed numerous Continental Airlines line pilots and asked them to describe the handling qualities of the 737-500 as compared to other versions of the 737 they fly. The majority of the pilots described the handling qualities as “squirrelly.”[32]

This description is consistent with empirical data shown in Attachment 6 of the Operations/Human Factors Group Factual Report. It states, “[m]ean heading variation (max-min) for the 737-500 during takeoff from 70-110 knots was 1.4 degrees and the mean plus one standard deviation was 2.2. The mean and the standard deviation for the other 737 types were approximately half as much.” In other words, larger heading changes are encountered during takeoff in the 737-500 giving the feeling of being less controllable, or “squirrelly.”

[27] Operations and Human Performance Factual Report Attachment 1, Page 69
[28] Operations and Human Performance Factual Report Attachment 1, Page 71
[29] Operations and Human Performance Factual Report Attachment 1, Page 61
[30] Operations and Human Performance Factual Report Attachment 6, Page 1
[31] Operations and Human Performance Factual Report, Page 29
[32] Operations and Human Performance Factual Report Attachment 1, Page 60

2.5.3 Multi-Purpose Engineering Can (M-Cab) Simulation

A "back-drive" simulation was created using the Boeing, multi-purpose engineering cab (M-Cab) to allow observers to see what the accident flight crew experienced. The back-drive recreated the visual scene from the cockpit, flight control inputs, and aircraft accelerations based on FDR parameters. The back-drive did not allow an observer to provide any control force inputs to the simulation.

The M-Cab was useful in taking all the FDR plots and putting it into a flowing visual field. This allowed the observers to see the movement of all the flight controls in conjunction with the visual field outside the flight deck. In addition, the M-Cab simulated the lateral acceleration or yaw motions that occurred.

There were statements made by Boeing personnel that the M-Cab represents exactly what the accident pilots saw. ALPA believes that this is an inaccurate statement. Although the visual cues may be similar to the accident flight, investigators cannot know where the pilot's attention was focused at any given time. During a takeoff roll, in addition to looking down the runway, a pilot is normally scanning all the cockpit cues relevant to the maneuver (e.g. airspeed and engine instruments). If a takeoff roll becomes more challenging due to internal or external threats, the pilot's scan adjusts to identify what the potential threat may be (windshear, crosswinds, power loss, etc.). In the M-Cab, the participants were focused on what they already knew was going to happen and when it was going to happen. For example, the two large rudder inputs, the final divergence from the centerline and if more rudder would have gotten them back on centerline.

When simulating the accident event in the M-Cab, the observer just followed along with the airplane. The observers basically had their hands and feet on the control surfaces and followed along with what they already knew was happening. This pre-programmed ride and assessment does not fully represent what the accident pilots experienced. A pilot utilizes the amount of deflection of a flight control and the amount of force required to move the control, coupled with the visual field to judge the effectiveness of those inputs in controlling the aircraft. In addition, any flight control input in response to a perceived change in aircraft motion or control position, would be delayed by normal human reaction time. By observing a back-driven event, without the ability to use a force to move the flight control, or know with certainty what cues were perceived and when, it is not possible to accurately and completely judge what the accident pilot felt or what might have been done to avoid the accident.

After flying the incident event over 60 times, if not careful, all of the observers could easily forget that the M-Cab was being used to re-create the visual scene from the cockpit, flight controls inputs, and aircraft accelerations based on FDR inputs. Even the most conscientious of observers given the absolute certain knowledge of what was coming, the ability to review what happened numerous times, and the ability to stop the simulation at any given time to assess the visual field, would have biased opinions of what the accident crew should or could have done. However, it must be noted that the accident pilots had only one opportunity to respond to any inputs.

A more useful way of utilizing the M-Cab would have been to take a random sampling of current line pilots, type-rated on the 737 give them no knowledge of what they were going to experience, run the accident flight one time and then interview them.

2.6 Air Traffic Control

The departure ATIS issued at 1753 MST, which the pilots of flight 1404 would have used to assist in determining the appropriate runway for departure, included wind information that was recorded by an Automated Surface Observing System (ASOS), located approximately 14,600 feet southeast of the accident site. While this information is for the airport in general, it did little to assist the pilots in their judgment on an appropriate runway for departure. Denver International Airport is a very large complex, with rapidly changing elevation features. It is also well known for out-of-the-ordinary wind conditions, demanding that the most accurate wind conditions are provided to flight crews for all aspects of the flight. It would be a tremendous asset to a pilot if the wind conditions for specific runways were provided in ATIS.

In the event that a flight crew elected to utilize a different runway than the active departure runways chosen by ATC, they would usually have to make that decision prior to requesting pushback from the gate area or initial taxi. Such a decision would have been based on several factors, to include wind information at the airport and ATC flow programs. The flight crew also used information provided by the company, such as ACCULOAD, which provides information based on a runway for departure, to include winds present at the time of its issuance. The pilots of flight 1404 received three additional ACCULOAD documents for three different runways prior to pushback.

During pushback from the gate area, the pilots of flight 1404 would have not necessarily been in an area to adequately judge the wind conditions coming from the west, due to those winds being blocked by terminal structures. The pilots also would have not been able to fully appreciate the wind conditions as they taxied, due to the airplane being taxied into the wind for a vast majority of the taxing time. As noted in the CVR transcript, the pilots did not mention the winds being encountered by the airplane until they were in the immediate vicinity of the runway 34R threshold.

As documented in the Air Traffic Control Factual Report, the tower provided wind information only from LLWAS sensor number 3 to flight 1404 for their departure from runway 34R. This sensor was located approximately 10,000 feet north and 3,400 feet east of the runway 34R threshold.

LLWAS sensor number 2 was the closest wind sensor to the threshold of runway 34R and had a reported wind of 35 knots at the time of flight 1404's takeoff clearance, which was almost a direct crosswind.[33] Sensor number 2 was not utilized by ATC, and thus the information which it provided was not relayed to the numerous departures on runway 34R, including flight 1404.

LLWAS sensor number 2 also recorded gusts, continuously, of 40 knots from 1816:22, through 1822:03.[34] Sensor number 2 was located approximately 1,400 feet north and 3,000 feet east of the runway 34R threshold.

[33] Meteorological Factual Report Table 4, Page 10-11
[34] Meteorological Factual Report Table 4, Page 10-11

There was no LLWAS sensor in the immediate area of where an airplane would be developing sufficient speeds for its track/flight path to be influenced significantly by the effects of wind forces on runway 34R. The closest sensor for that area would have been located 5,800 feet north and 4,900 feet west. There is also a substantial elevation drop and rise between this sensor and runway 34R, possibly making the actual wind encountered on the runway considerably different than that which was measured at the sensor.

Recorded meteorological data reveals that there were significant gusty winds in the area at the time of flight 1404's departure. In this event though, no wind gust information for runway 34R was available to ATC and therefore was not relayed to the pilots of flight 1404 before or after their pushback from the gate area, during the taxi, or from their takeoff clearance on runway 34R.

3.0 Findings

1. The flight crew was properly certified and qualified under federal regulations and Continental Airlines training requirements, to operate the aircraft.
2. The winds reported on the ATIS and provided to the crew during the takeoff clearance were both within the crosswind guidelines in the Continental 737 AFM.
3. The winds recorded by the LLWAS sensor closest to the departure end of the runway were in excess of the crosswind guidelines in the Continental 737 AFM, but these winds were not relayed to the crew.
4. The flight crew was cognizant of crosswind conditions.
5. During the takeoff roll, the Captain applied crosswind correction techniques and applied cyclical rudder inputs, which are normal during crosswind takeoffs.
6. The Captain applied what he felt was full right rudder twice. After the second application, the Captain perceived that the input was not having the desired effect and attempted to keep the aircraft on the runway using the tiller.
7. The wind conditions and values, as calculated by Boeing and the NTSB Airplane Performance Group, exceeded the aircraft capability.
8. The Continental Airlines Flight Manual does not accurately reflect demonstrated crosswind component values, as provided by Boeing and Aviation Partners Boeing.
9. Denver International Airport lacked enough LLWAS sensors to ensure adequate coverage to detect the gusty wind conditions encountered by flight 1404.
10. The ATC system was deficient in providing current and accurate (closest) wind information to pilots, to determine the best course of action for the flight.

4.0 Recommendations

To the Federal Aviation Administration:

1. Ensure airports with scheduled air carrier operations, both passenger and cargo, assess the need for additional LLWAS sensors to ensure flight crews have accurate wind information for their departure and landing runways.
2. Establish and implement a process that provides all controller stations access to real-time wind data for all areas of the airport complex.
3. Reevaluate the manner in which dissemination of wind reporting to airmen is conducted by air traffic controllers in the event that immediate vicinity threshold wind sensors are not installed.
4. Require the installation of anemometers, with gust reporting capabilities, for all runway thresholds, and their mid-points, at the Denver International Airport.
5. Ensure that when wind velocities are in excess of 10 knots, wind values are provided to aircraft for approach end, mid-point, and departure end of the runway (if available).
6. Require aircraft manufactures to provide operators with an established crosswind takeoff and landing limitation for each aircraft model.
7. Require aircraft manufactures to provide operators with an established handling and control techniques for each aircraft model in crosswind take-off and landing conditions.
8. Require aircraft manufactures to provide the NTSB with the aircraft simulation model for the event aircraft type/ model.
9. Ensure aircraft training simulators can simulate realistic crosswind and gusty wind conditions and the fidelity is representative of the aircraft being simulated.
10. Ensure airlines as part of their training program implement crosswind and gusty wind conditions into initial and recurrent simulator training.