Attachment 3

To the Operations / Human Performance Group Chairmen’s Factual Report

Operational Study

DCA09MA021

Observational Study

Five airline transport pilot members of the operational factors / human performance group, four of whom were type-rated on the B-737 and one of whom was a B-737-rated Boeing test pilot, participated in an observational study at Continental Airlines training center in Houston, Texas on January 27, 2009. The purpose of the study was to familiarize the group with company standard operating procedures for crosswind takeoffs, to evaluate the effect of varying crosswind conditions on the subjective difficulty of takeoffs, and to evaluate the effect of varied control inputs on simulator response. The simulator used for the observations was an FAA certified level D B-737-500 simulator (FAA identification number #473).

Familiarization with Crosswind Takeoff Procedures

Crosswind takeoff procedures were demonstrated by two assistant Boeing B-737 fleet managers employed by Continental Airlines who were type rated and current on the B-737-500. Crosswinds of 0 knots, 25 knots, 35 knots, and 31 gusting to 37 knots were used for the demonstrations. Simulator motion was turned off during the demonstrations so all group members could simultaneously observe.

After each takeoff, the assistant fleet manager who was flying the takeoffs from the left seat rated the subjective difficulty of the maneuver using a scale of 1 to 7, with 1 being “very easy,” 2 being “moderately easy”, 3 being “slightly easy”, 4 being “neither difficult nor easy”, 5 being “slightly difficult”, 6 being “moderately difficult”, and 7 being “very difficult”. He rated the zero wind takeoff as a 1 (“very easy”), the 25 knot and 35 knot crosswind takeoffs as being a 5 (slightly difficult”), and the 31 gusting to 37 knot takeoff as being a 6 (“moderately difficult”).

During crosswind takeoffs, the assistant fleet manager was observed putting in left aileron correction as the airplane got up to speed, lessening that correction as the airplane got closer to rotation, adding more in as the airplane rotated, and then adjusting wheel inputs as needed to keep the wings level. He was also observed using varying amounts of rudder inputs to keep the airplane aligned with the runway centerline until rotation, and neutralizing the rudder after becoming airborne. When on the runway, right rudder was added when the nose yawed to the left, and it was quickly reduced when the nose began to move back toward the centerline.

The assistant fleet managers said the takeoffs were made more difficult by the absence of simulator motion, because motion was useful for cueing the control inputs needed to keep the airplane on the centerline and the wings level. They stated that the crosswind takeoffs were a much more “visual” task with the simulator motion off.

Effect of Crosswind on Subjective Difficulty of Takeoff Maneuver

Each ATP-rated group member performed a simulated takeoff at night on Denver International Airport’s runway 34 right under four different direct crosswind conditions: 0 knots, 25 knots, 35 knots, and 30 gusting to 40 knots. Wind conditions were presented in counterbalanced order. Maneuvers were performed with the simulator motion turned on. The simulator was programmed

with an airplane gross weight of 117,000 lbs, 20,000 lb fuel load, and a 21.5% MAC center of gravity. The programmed temperature was -6 degrees Celsius.

After each takeoff, the flying pilot rated the subjective difficulty of the maneuver on a scale of 1 to 7, with 1 being "very easy," 2 being "moderately easy", 3 being "slightly easy", 4 being "neither difficult nor easy", 5 being "slightly difficult", 6 being "moderately difficult", and 7 being "very difficult". Ratings provided by the group's five ATP-rated pilots are displayed in Table 1 below.

Table 1.
Subjective difficulty ratings of four takeoffs conducted under differing crosswind conditions.

Participant	0 knot cross-wind	25 knot cross-wind	35 knot cross-wing	30 knot gusting to 40 knot cross-wind
1	1	4	5	6
2	1	2	5	5
3	1	3	5	4
4	1	5	5	5
5	1	4	5	5
Median	1	4	5	5

The group's pilots were given the opportunity to provide comments after performing each maneuver. They described the no-wind takeoff as "easy". One said "It's what we do."

Comments on the 25 knot crosswind takeoff included the following. "I was working the rudder a bit early in the takeoff. It was nothing while rolling on the runway. It is what we do on the line. Almost no rudder at liftoff."

Comments on the 35 knot crosswind takeoff included the following. "Had to work at it. Could feel left wing come up a bit at 90 knots. It wanted to weathervane more than expected at 100 knots. Maximum displacement from the centerline occurred at 100 knots. Had a hard time determining the right amount of rudder. No more than half rudder required. It took some rudder, but less than half of the available travel."

Comments on the 30 gusting to 40 knot crosswind takeoff included the following. "Control on the runway about what you would expect. Maximum rudder was half travel or less. More difficult at higher speed. Felt the gusts beyond 100 knots that time. Felt pretty much the same, almost seemed to require less rudder than the 35 knot crosswind. Need left aileron after rotation. Straightforward, not a big deal, you don't notice it until you are in the air."

After completing takeoffs in all four wind conditions, some group members provided additional comments, including the following. "Same as my previous experience, pretty easy. Don't feel lateral g like in the real airplane, can feel and see the wing pick up easier in the real airplane. 1/3rd to ½ rudder travel was maximum required. Did not have much aileron in until rotation. Just do what you have to to keep the wings level. Overall didn't seem that difficult. Did not need aileron during ground roll."

In addition to these four trials, two of the group's ATP-rated pilots attempted to take off in a 60-knot crosswind and were able to do so without crashing the simulator. Although this required more right rudder correction than needed in the other four conditions, some reserve rudder authority was still available during the maneuver.

Effect of Varied Control Inputs on Simulator Response

In order to examine the effect of varied control inputs on simulator response, all group members performed the following maneuvers in a steady 35-knot direct left crosswind, beginning at the approach end of the runway, just before the runway identification numbers. Each pilot was fully briefed on the maneuver before it was attempted. A pilot in the right cockpit seat made the 90-knot callouts and an observer with a timer called out the end of the required time interval.

1. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots.
2. With rudder trim adjusted to 1.5 degrees left, begin takeoff roll normally, remove feet from rudder pedals at 90 knots.
3. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots, move control wheel to the right (to maximum of full travel) at 100 knots.
4. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots, attempt to maintain directional control using tiller.
5. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots, wait 2 seconds (until signal given by an observer with a timer), then resume directional control inputs with rudder and attempt to complete the takeoff.
6. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots, wait 3 seconds (until signal given by an observer with a timer), then resume directional control inputs with rudder and attempt to complete the takeoff.
7. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots, wait 2 seconds (until signal given by an observer with a timer), then resume directional control inputs with rudder and perform a rejected takeoff.
8. Begin takeoff roll normally, remove feet from rudder pedals at 90 knots, wait 3 seconds (until signal given by an observer with a timer), then resume directional control inputs with rudder and perform a rejected takeoff.

Outcomes in the 8 conditions were as follows.

1. Airplane began turning to the left after removal of rudder and exited the runway about 5 seconds later, at the 9,000-feet-remaining marker, at an airspeed of about 120 knots. Tire scrubbing vibrations and sounds began just before exiting the runway.
2. Airplane began turning to the left after removal of rudder. The turn was more rapid than in condition 1. The airplane exited the runway about 4.8 seconds later, approximately 300 feet before the 9,000-feet-remaining marker. Tire scrubbing vibrations and sounds began about halfway between the runway centerline and the side of the runway.
3. Same as condition 1. Application of right aileron had little effect.
4. Airplane began turning left. The turn was less rapid than in condition 1. The airplane exited the runway several hundred feet beyond the 9,000-feet-remaining marker. Tire

scrubbing vibrations and sounds began soon after the application of tiller. These vibrations were stronger/louder than in conditions 1-3.

5. All pilots were able to salvage the takeoff with skidding on the runway. Three participants judged this condition a 6 (“moderately difficult”), two judged it a 4 (“neither difficult nor easy”).
6. Two pilots were unable to take off before one or more landing gear exited the runway. Three were able to take off on the runway, with “fishtailing.” Three rated the maneuver’s difficulty a 7, one a 6.5, and one a 5.
7. All pilots were able to stop on the runway, but the maneuver resulted in excessive “fishtailing.” Three participants rated the maneuver’s difficulty a 5, two a 6.
8. Three pilots were able to stop on the runway, whereas some departed the runway while stopping the airplane. All five rated the maneuver’s difficulty a 7.

In addition to performing the maneuvers in these 8 conditions, participants were given the opportunity to view the visual scene from the cockpit with a heading displacement 4 degrees left of the runway centerline and 16 degrees left of the runway centerline. All stated that the 16-degree offset appeared to be about the same heading they were on when they departed the runway in condition 1.

One of the group’s pilots performed an additional takeoff with the 35-knot crosswind, using rudder compensation as necessary until 70 knots. At 70 knots, the pilot made a full right rudder input lasting about two seconds and then released the rudder. At 83 knots, the pilot made another full right rudder input lasting about two seconds and then released the rudder. As the first rudder input was made, the airplane deviated to the right of centerline. After the first rudder input was released, the airplane returned to the centerline. As the second rudder input was made, the airplane deviated to the right side of the runway, near the right edge lights. After the second rudder input was released, the airplane turned to the left, exiting the left side of the runway at the 8,000-feet-remaining marker.

Joint Comments

After all conditions were completed, participants assembled to offer observations in a group setting. These included the following.

- The simulator was not as good as the real airplane for providing a seat of the pants feel for wind gusts. It did not accurately reflect lateral accelerations.
- Maintaining the centerline during crosswind takeoffs was consistently achievable in all crosswind conditions. Maximum rudder needed for crosswinds up to 35 knots felt like between 1/3 and 1/2 of full travel.
- Participants appeared to put in a big rudder correction in response to perceived changes in yaw and relax the input as soon as the airplane began to respond.
- Taking off in 35 knots or more of crosswind required continuous adjustment and close monitoring of rudder inputs.
- Not a lot of rudder correction was required with 35 knots of crosswind, but the pilot really needed to correct for it. After relaxing the rudder to zero, bad things happened in a hurry.

- Application of full right aileron after 100 knots had a negligible effect on directional control.
- It was impossible to maintain directional control in a 35 knot crosswind when rudder was relaxed and the tiller was used instead. As this was attempted and did not work, it felt counterintuitive to ease up on the tiller.
- While attempting to use the tiller for directional control, one participant was seen taking his right hand off the thrust levers and putting it on the wheel. When questioned about it afterward, this participant did not remember doing so. Others could not remember what they did with their right hand, and this was not specifically monitored by observers.
- When rudder trim was set to 1.5 degrees left in a 35 knot crosswind condition, the airplane turned off the runway more quickly when rudder correction was relaxed, but the effect of rudder trim was not noticeable when rudder correction was maintained.
- A 2 second removal of rudder correction after 90 knots resulted in a situation that was salvageable but required full-travel rudder corrections. 2 seconds would be about the point of no return for a reliable recovery.
- A 3-second removal of rudder correction after 90 knots resulted in a situation that would definitely be unmanageable for a line pilot who was not expecting to have to perform the maneuver.
- The 2 and 3 second delay scenarios were not identical to the accident scenario because, among other things, participants were holding steady on the centerline with small to moderate rudder correction before the large yaw event, whereas the accident crew made two full, or nearly full, rudder inputs to stay on the centerline before the big yaw. Also, unlike the accident flight crew, the participants did not have to decide whether to continue or reject, but made the decision in advance.