Submission to the

National Transportation Safety Board

for the

Delta Airlines MD-88 N909DL
Runway excursion at LaGuardia Airport
New York City
05 March 2015

The Boeing Company
05 July 2016

INTRODUCTION

On March 5, 2015, at about 11:02 Eastern Standard Time, a Boeing MD-88, registration number N909DL, was operating as Delta Air Lines flight 1086 and exited the left side of runway 13 while landing at LaGuardia Airport, New York, New York. After exiting the runway, the aircraft contacted the airport perimeter fence and came to rest with the airplane nose on an embankment next to Flushing Bay. The airplane was substantially damaged, and some of the 127 passengers received minor injuries. The three flight attendants and two flight crew were not injured. Flight 1086 was a regularly scheduled passenger flight from Hartsfield-Jackson Atlanta International Airport (ATL) operating under the provisions of 14 Code of Federal Regulations (CFR) Part 121. Instrument meteorological conditions (IMC) prevailed, and an instrument flight rules (IFR) flight plan was filed

Submission Abstract

- The Boeing Company, as the airplane’s manufacturer, is an invited party to the investigation and provides technical and operational assistance to the National Transportation Safety Board (NTSB) in their investigation.
- The conclusions presented in this submission are based on factual information received from the NTSB, Boeing expertise, the use of analytical tools, and a methodical investigation process
- The investigation did not reveal any anomalies with the airplane or its systems that contributed to the accident.
- During landing rollout, a recommended Reverse EPR (Engine Pressure Ratio) limit was exceeded, contributing to the runway excursion.
- Reverse thrust was applied before Nose Gear (NG) touchdown, contrary to published procedures
- Both aircraft engines were prematurely shutdown hampering the subsequent evacuation.

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BOEING ASSISTANCE WITH THIS INVESTIGATION

The National Transportation Safety Board (NTSB) is conducting the investigation into this Delta Airlines MD-88 accident. Assisting the NTSB in their investigation are the Federal Aviation Administration (FAA), Delta Airlines, Air Line Pilots Association (ALPA) Boeing, and other designated parties.

As the manufacturer of the MD-88 airplane, Boeing's specific role in this investigation has been to provide technical information regarding the airplane design, manufacture and operation to assist the NTSB.

Furthermore, the NTSB requested that all parties submit proposed findings to be drawn from the factual information established during the course of the investigation. Boeing has responded to the NTSB request with this document, which:

- Provides an assessment of the factual information and other pertinent data.
- Identifies knowledge gained from the investigation.
- Identifies conclusions supported by the knowledge gained from the investigation.

BOEING ASSESSMENT

The Boeing assessment of the accident is based upon the facts as documented in the NTSB's factual reports. These reports are observations of the airplane and accident site, post-accident examination of airplane systems and components, flight data recorder (FDR) data, the cockpit voice recorder (CVR) transcript, and flight and cabin crew interview data.

AIRPLANE SYSTEMS

The investigative group met at LaGuardia Airport from March 6 – 12, 2015 to document the relevant airplane powerplants, structure, and systems. When the group arrived, the airplane had already been moved from the airport field (accident site) to a maintenance hangar. The group documented the airplane inside of the hangar.

The group identified and documented the following relevant systems of the airplane for the investigation:
Communications, Electrical Power, Equipment & Furnishings, Flight Control Systems and Surfaces, Fuel, Hydraulics, Ice and Rain Protection, Instruments, Landing Gear, Nose Wheel Steering,

At the end of the on-scene phase of the investigation, the following airplane components were removed and retained by the National Transportation Safety Board for further examination.

1. Anti-skid control unit
2. Auto brake control unit
3. Anti-skid valves, 4 total
4. Wheel speed transducers, 4 total
5. Auto spoiler switching unit
6. Auto spoiler control box
7. Auto spoiler actuator in pedestal
8. EGPWS (Enhanced Ground Proximity and Warning System)
9. PSEU (Proximity Switch Electronics Unit)
10. Nose wheel steering control valve
11. Brake pressure transducers for flight data recorder (FDR), 2 total
12. Auto brake flight deck panel
13. Digital Flight Data Acquisition Unit (DFDAU)
14. Lateral Control Position Sensor for the FDR
15. MiniQAR

None of the evidence gathered on-scene or examinations of the removed components revealed a failure of an airplane system. There were no pre-impact discrepancies found in the aileron, elevator, or rudder flight control systems.[1]

WEATHER

The official weather prior to the accident reported by the Automatic Terminal Information Service (ATIS) at 1551 UTC (1051 EST, 11 minutes prior to the accident) at LaGuardia was wind from 30° at 11 kts. Visibility was 1/4 mile, vertical visibility 900 ft, and precipitation was snow and freezing fog. The temperature was -3°C (26°F), dew point -5°C (23°F), and the altimeter setting was 30.12 inHg [2]. METARS indicated 0.06 inches of precipitation had accumulated during the last hour. Snow was reported to be falling at a rate of ¾ inch per hour at the time of the accident.

[1] NTSB Airworthiness Group Chairman's Factual Report, Dated Feb. 4, 2016, Pg. 7.

The ATIS reported that braking action advisories were in effect. The runways were reported wet and sanded and de-iced but had 1/4 inch of wet snow. It was noted that all runways and taxiways had a three foot snowbank along their edges.[2]

AIRPLANE PERFORMANCE

The aircraft was on the appropriate glide slope and heading on approach into LGA. It touched down at 133 kts, consistent with a Vref of 131 kts (+ 5 kts). The aircraft's main gear touched down 600 ft from the runway threshold and nose gear touched down at 1200 ft. Braking devices all deployed in the time between main gear and nose gear touchdown. The aircraft began to experience a left yawing moment about 1600 ft down the runway. The crew applied right rudder, but the aircraft's heading followed the left yaw and the aircraft exited the left side of runway 13 about 3200 ft from the runway threshold.

Boeing released guidance to limit reverse thrust EPR to less than 1.6 during normal landings and less than 1.3 EPR when landing in adverse conditions. This guidance was based on test data that showed that the rudder has limited directional authority for aircraft reverse thrust EPR values above 1.6 and airspeeds below 146 kts, and similarly has limited directional authority for aircraft reverse thrust EPR values above 1.3 and airspeeds below 108 kts. The engine pressure ratios for the engines in reverse thrust exceeded 2.0 for the left engine and 1.9 for the right engine, and the EPR levels exceeded 1.6 for approximately five seconds. The high EPR values had the effect of blanking the rudder during the aircraft's left heading deviation and rendered rudder input ineffective. Once the thrust reversers were stowed and rudder authority was restored, application of right rudder (in conjunction with nose wheel steering and differential braking) was effective in arresting the increase in the left yaw rate. While the rudder was blanked, nose wheel steering input from the rudder pedal likely contributed to slowing the aircraft's yaw rate, but was not sufficient to redirect the airplane until used in conjunction with effective rudder. Differential right manual braking also contributed to controlling the aircraft's heading, but was also applied after the thrust reversers were stowed (4.5 seconds after the initial yaw rate increase).

On the day of the accident, New York was experiencing a winter storm. On landing the aircraft was subject to a 10 kts crosswind from the left and the runway was contaminated with snow. However, the wheel braking coefficients for the accident aircraft and the previous MD-88 were determined to be about 0.16 (which would be considered medium according to Advisory Circular 25-32) or better.

The circumstances at the time of the heading deviation are considered outside the envelope of valid test data for the airplane, so there is substantial uncertainty in evaluating the relative contributions of the different systems or environmental factors. The possible forces that may have precipitated the heading deviation include a yawing moment imparted by asymmetric reverse thrust, a sudden increased crosswind, or differential runway friction. The data was incomplete or the effects of these forces on the aircraft were not measured and/or accurately modeled for the exact contribution of each to be determined. What data was available did not make any single event or environmental factor seem likely on its own to be able to impart the yawing moment experienced by the accident aircraft. It is likely that a combination of

[2] NTSB Performance Study, Dated May 25, 2016, Pg. 3

asymmetric thrust, crosswind, and runway friction caused the aircraft to deviate from the runway heading.

Analysis of 78 other landings of the accident ship and the prior MD-88 aircraft showed that EPR values in excess of 1.6 were common even when landing in reported precipitation or with a crosswind. None of the other 78 landings showed a significant deviation in heading. Additionally, rudder input direction was more strongly correlated with EPR split direction than crosswind direction. However, of the all the landings examined the accident landing had the highest recorded EPR values and the shortest time between main gear touch down and exceeding 1.6 EPR.[3]

SURVIVAL FACTORS

A survival factors group was formed on April 6, 2015. Interviews were conducted with the flight attendants (F/A), Delta Air Lines (DAL) personnel, and a Federal Aviation Administration (FAA) cabin safety inspector (CSI) for DAL. Flight attendant training and DAL manuals were reviewed, and records were collected.

The accident occurred on the first flight of a 3-day trip for the flight attendants.
A passenger seated in a window seat at row 33, aft of the left wing described the landing and subsequent runway departure as "not being violent" but stated that he felt they "were in a very dangerous situation." The F/As described the landing as "feeling different," as though it was not controlled, and one described the airplane coming to rest as it "just stopped, not severely or abruptly, but just stopped, almost gentle."

The F/As shouted the commands "stay seated, stay calm." A passenger pointed to the middle of the cabin, and F/A 1 unbuckled her restraint and moved toward the middle cabin where the passenger had pointed. She found a female passenger who appeared to be crying but was not injured.

F/A 2 remained buckled in her jumpseat. She did not hear anything from the flight deck or from the FL. She tried to use the interphone to reach the flight deck and the FL but was unable to because the airplane had no power.

At the tailcone, F/A 3 was shouting commands to "stay seated, stay calm." She stated that it felt like a long time while waiting for a command from the captain. Hearing none, she unbuckled from her jumpseat and began to check on passengers. F/A 2 and F/A 3 both walked forward to the front of the cabin, informing passengers to stay in their seats and to stay calm. When the captain came out of the cockpit, F/A 1 returned to the area of the forward flight attendant station to speak with him. He asked if the forward exits were usable. She had seen water outside the left-side windows, and advised that the forward doors were not going to be available.

As F/A 2 and F/A 3 approached the front of the cabin, they saw the water and the damaged left wing for the first time. F/A 3 told the captain she had assessed the overwing window exits as

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[3] NTSB Performance Study, Dated May 25 2016,Pgs. 48-49

she walked forward and determined the right side was usable. He asked about the tailcone, and she said, “I don’t know.”

Because all of the flight attendants were in the front of the cabin and no one was monitoring the aft cabin, F/A 2 decided to return to the back of the cabin. As she walked aft, a passenger stopped her and pointed to a first responder that was motioning for him to open the overwing window exit. She told the passenger “no, we need to wait until our captain instructs us to evacuate.”

The captain told F/A 1 and F/A 3 they needed to prepare to evacuate. As F/A 3 returned to the aft cabin, she noticed passengers on cell phones and began shouting, “Get off your cell phones right now, we need to evacuate, we need to prepare to evacuate, you need to listen to us, get your coats on.”

The captain handed F/A 1 a megaphone and told her to begin an evacuation. Using the megaphone, she told the passengers they were going to evacuate. She told them they needed to put on their coats and, because she did not know how slippery the wing would be; and she told passengers wearing high heels to remove them. Even though F/A 1 was using the megaphone, the passengers in aft cabin could not hear her. She moved closer to the overwing exits and told passengers they were to evacuate using the right-side overwing exits. She told the passengers seated there to open the overwing exits and put the exit hatches on the seats. The passengers opened the right-side overwing exits and began to evacuate. F/A 1 asked for assistance from able-bodied passengers to stand outside and help people off the wing.

Firefighters were standing on ladders at the wing “yelling at passengers to hurry and get away.” A firefighter told F/A 1 fuel was leaking under the left wing. She did not want to panic passengers, so she moved them along as fast as she could. She directed older passengers and children to the back tailcone as she thought it would be easier for them to exit there. It was not until she exited the airplane that she realized the tailcone had no slide.

When F/A 3 opened the tailcone, she “saw water” and immediately closed the door, assuming it was unusable. With the megaphone, she commanded “bad exit, go forward!” A passenger pointed out the water might have been from a firefighter’s hose. She opened the exit again and could “see snow, but no slide.” She gave the megaphone to a passenger and told him to “keep people back until I get the slide.” She proceeded down the catwalk, lifted the slide cover handle, and pulled the manual inflation handle. At this time, the firefighters were yelling at her to “jump” but she remained on the catwalk. Once she pulled the inflation handle she heard the slide “explode,” but she could see not see it. She did not understand the attitude of the airplane at the time and that the slide had inflated under the airplane. She commanded passengers to come to the edge of the tailcone, sit down, and jump to the ground.

The passengers who exited through the tailcone were instructed to leave all of their belongings, except for their jackets. A passenger discussed with other passengers whether to take their computer bags and agreed that they should. They felt “slightly guilty” about this decision. They agreed to leave the overhead luggage, even though they knew they “would not be seeing luggage anytime soon.”

The lavatories were checked by F/A 1 and F/A 2, and F/A 1 told the captain everyone had evacuated. F/A 2 and F/A 3 exited out of the tailcone together. It was then F/A 2 also realized there was no slide for passengers to use. F/A 1 and the flight crew also exited out of the tailcone.

In summary, according to the examination of the photographs and videos about 6 minutes after the aircraft came to a stop was the first indication on the videos the passengers were told they were going to evacuate the aircraft; and about 9 minutes later before videos show passengers exited the aircraft. It was over 17 minutes after the aircraft came to a stop that the passengers were evacuated.[4]

This evacuation was hampered by the complete lack of ship's power after the aircraft came to rest, due in large part to the premature shut down of both engines. Evidence indicates the engines were shut down while the aircraft was in motion.

OPERATIONS:

The investigative evidence gathered and presented in the various NTSB factual reports suggest this accident can be attributed to operational issues before, during, and after touchdown at LGA.

Securing of engines during rollout:
Pilot interviews along with FDR data have determined that both engines were shut down after the aircraft departed the runway but prior to coming rest. This action was taken independently by the copilot and not in accordance with accepted or published procedures

From an interview with the First Officer.
"He was concerned they would go in the water so, without asking permission, he shut down the engines to prevent any further thrust from pushing them over into the water"[5]

This action contributed to the complete lack of power and ships communication during the subsequent evacuation.

Deployment of thrust reverser and initial application of reverse thrust during landing roll:

The normal landing roll procedure in the Delta MD88/90 AOM, Volume 1, page NP.20.76 stated "after main gear touchdown and once nose lowering had commenced thrust reversers may be deployed to reverse idle detent. Upon nosewheel touchdown, normal reverser should be used."

As detailed in the NTSB Performance Study upon main gear touchdown with engines at idle, the left was 1.1 EPR and right was 1.0 EPR. While the nose gear was still in the air during the derotation phase of landing and with Thrust Reversers deployed, approximately 1.25 EPR was on left engine and 1.15 EPR was on right engine.[6]

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[4] NTSB Survivals Factors Group Factual Report, Dated Feb. 9, 2016 Pg. 16.

[5] NTSB Operations Group Factual Report, Dated April 24, 2016 Attachment 1 , pg. 4

[6] NTSB Performance Study, Dated May 25 2016, Figure 15, Pg. 17

This reverse thrust application prior to nose gear touchdown is contrary to published procedures and although early in the landing rollout, would have resulted in a nose left tendency.

Exceedance of Thrust Reverse EPR limits:

For the MD-80 family of aircraft, both the Boeing and Delta flight guidance material correctly detail an operational limit with regard to the level of reverse thrust to be applied during reverser operation. Limits of 1.6 EPR on dry runway conditions and 1.3 EPR on wet or contaminated runways is detailed. The runway conditions during this landing were contaminated and reverse thrust should have been limited to 1.3 EPR. Exceedance of published limits could have a negative effect on keeping the aircraft aligned to the runway centerline.

During the accident landing and rollout, reverser thrust exceeded 2.0 EPR. During the investigation, data from numerous prior flights of the accident aircraft were reviewed. Although not to the degree of the accident landing, the recommended reverse EPR were routinely exceeded.[7]

Thrust Reverse use during landing rollout.

During landing rollout, if difficulty maintaining runway centerline is noted, the Boeing flight crew guidance material recommends reducing reverse EPR to reverse idle, and **if necessary select forward idle**, to reestablish directional control.

The DAL produced MD-88 flight crew guidance materials appear to be inconsistent regarding the application of reverse idle and forward idle thrust when directional control issues are encountered during landing rollout. .

Section 6.16 of the DAL produced MD-88 FCTM Landings states to reduce reverse thrust to reverse idle, and if necessary, to forward idle.

"If a skid develops, especially in crosswind conditions, reverse thrust will increase the sideward movement of the airplane. In this case, release brake pressure and reduce reverse thrust to reverse idle, and if necessary, to forward idle.
Apply rudder as necessary to realign the airplane with the runway and reapply braking and reversing to complete the landing roll."

Section 6.25 of the DAL produced MD-88 FCTM (Attachment 16 to the NTSB Flight Operations Report) states to reduce reverse thrust to idle, but does not mention the recommendation to select forward idle as required to reestablish directional control:

"*This figure shows a directional control problem during a landing rollout on a slippery runway with a crosswind. As the aircraft starts to weathervane into the wind, the reverse thrust side force component adds to the crosswind component and drifts the aircraft to the downwind side of the runway. Also, high braking forces reduce the capability of the tires to corner. To correct back to the centerline, release the brakes and reduce reverse thrust to*

[7] NTSB Performance Study, Dated May 25 2016Pg. 49.

reverse idle. Releasing the brakes increases the tire-cornering capability and contributes to maintaining or regaining directional control. Setting reverse idle reduces the reverse thrust side force component without the requirement to go through a full reverser actuation cycle. Use rudder pedal steering and differential braking as required to prevent over correcting past the runway centerline. When directional control is regained and the aircraft is correcting toward the runway centerline, apply maximum braking and symmetrical reverse thrust to stop the aircraft."

The above guidance (Section 6.25) is more appropriate to Boeing -7 series aircraft with wing mounted engines.

KNOWLEDGE GAINED DURING THE INVESTIGATION (Findings)

The following knowledge gained is pertinent to drawing conclusions:

- The investigation did not reveal any anomalies with the airplane or its systems that contributed to the incident.
- The investigation indicates the conditions of runway 13 reported to the flight crew were wet and sanded/deiced but had ¼ inch of wet snow.
- .The investigation indicates excessive reverse thrust was commended by the flight crew during landing rollout. Boeing's published procedures state 1.6 is the maximum allowable EPR that should be utilized during reverser thrust application on dry runways and 1.3 is the maximum allowable EPR that should be utilized on wet or contaminated runways. Engine Pressure Ratios up to 2.0 were commanded by the flight crew during the event landing rollout.
- The investigation indicates that both reversers were deployed and reverse power was applied prior to nose gear touchdown contrary to Boeing's published procedures,
- Both engines were shut down before the aircraft came to rest.

CONCLUSIONS

Boeing believes that the evidence supports the following conclusions for the accident:

- The Boeing Company, as the airplane's manufacturer, is an invited party to the investigation and provides technical and operational assistance to the National Transportation Safety Board (NTSB) in their investigation
- The conclusions presented in this submission are based on factual information received from the NTSB, Boeing expertise, the use of analytical tools, and a methodical investigation process.
- The investigation did not reveal any anomalies with the airplane or its systems that contributed to the incident.
- The recommended Reverse EPR limit was exceeded

- Reverse thrust was applied before NG touchdown, contrary to Boeing's published procedures.
- Both engines were prematurely shutdown, hampering the subsequent evacuation.

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