Investigating a MD-88 Runway Excursion

Joshua Migdal
Air Safety Investigator, Delta Air Lines, Inc.

Joshua Migdal is a Senior Air Safety Investigator with the Delta Air Lines Flight Safety Department. He received a Master of Science in Safety Science from Embry-Riddle Aeronautical University Prescott. As an investigator at Delta Air Lines, he is responsible for conducting internal incident investigations and functioning as an NTSB liaison and party coordinator. He holds a FAA commercial pilot and Flight Instructor certificate with an instrument rating and has flown fixed and rotary wing aircraft.

On March 5, 2015, a Boeing MD-88, N909DL, operating as Flight 1086, departed Atlanta, GA (ATL) bound for New York, NY (LGA). The flight crew was aware of the winter storm that was impacting the New York area. During cruise, the flight crew discussed the weather, runway conditions, landing distances, and diversions. As the flight approached New York airspace, the flight crew was assigned holding due to runway clearing operations. Subsequently, the flight crew was informed of GOOD pilot reported braking actions and they were cleared for the instrument landing system (ILS) approach to runway 13. At 300 feet, the flight crew observed a completely snow covered runway, which was not anticipated. The approach was continued and the aircraft touched down approximately 600 feet beyond the runway threshold.

Upon touch down, the first officer manually deployed the speedbrakes and the captain activated the thrust reversers. As the nose landing gear touched down, the captain applied reverse thrust and the aircraft began to slide to the left. At that time, the flight crew did not observe a normal deceleration, and the aircraft continued in a leftward movement. The first officer then informed the captain to discontinue the use of reverse thrust. The captain deactivated the reverse thrust and the aircraft continued to slide to the left despite the captain’s right steering inputs. Subsequently, the aircraft departed the runway surface at approximately 80 knots.

After departing the runway surface, the aircraft traveled across a grassy area before striking a seawall. The aircraft traveled parallel to the seawall, impacting the airport perimeter fence for approximately 1,000 feet before turning sharply to the left. The aircraft stopped with the nose suspended over Flushing Bay and fuel leaking from the left wing. *See Figure 1.* Subsequently, aircraft rescue and firefighting (ARFF) personnel arrived and an evacuation was initiated.

Figure 1: Photograph of the aircraft’s final resting location (NTSB).

The aircraft sustained substantial damage and 29 of the 131 passengers and crew on board received minor injuries. This event was classified by the National Transportation Safety Board (NTSB) as a damage accident. This article outlines the investigation’s findings[i] and reviews the safety actions implemented to prevent future events.

Investigation Overview

Delta Air Lines and the NTSB launched investigative go team members to LGA and ATL. Additional party members included representatives from the Federal Aviation Administration (FAA), Boeing, Air Line Pilots Association, International (ALPA), and the Port Authority of New York and New Jersey. Investigation team members gathered in New York, Atlanta, and Washington, D.C. to begin the process of reconstructing the sequence of events that contributed to the accident. Focus areas included operations/human performance, vehicle performance (recorder data), and airport operations.

Operations

To better determine the runway conditions, the flight crew utilized the automatic weather updates through the aircraft communications addressing and reporting system (ACARS) and requested braking action reports. En route, the flight crew noted that they were initially unable to obtain braking action information. Their interpretation of the runway's conditions were based on Notice to Airmen (NOTAM) reports that the runways were wet, sanded, and chemically treated. Even with these conditions, the flight crew identified a requirement for braking action of GOOD or better to land by reviewing the MD-88 operational landing distance charts.

During descent, the flight crew prepared to enter holding due to runway clearing operations. As they continued the descent, the air traffic controller informed the flight crew that the runway was open. Subsequently, POOR braking action was reported and a preceding aircraft initiated a diversion. A short time later, an Airbus aircraft reported GOOD braking action and the preceding aircraft elected to land at LGA. Based on reports of GOOD braking action, the flight crew elected to land.

On final approach, the flight crew observed the approach lighting at approximately 400 feet and the runway at approximately 300 feet. The flight crew noted that the runway was snow covered, which was not what they anticipated, based on previously received field condition reports. The flight crew elected to continue the approach based on the reports of GOOD braking action.

Vehicle Performance

A performance study indicated that the aircraft touched down at 133 knots, approximately 600 feet from the runway threshold. Approximately 1,600 feet from the runway threshold, a left yawing moment began and the flight crew applied right rudder. During that time, the reverse thrust engine pressure ratio (EPR) exceeded 2.0 and 1.9 for the left and right engines, respectively. Subsequently, the thrust reversers were stowed and manual braking was applied. The aircraft exited the paved surface 3,200 feet from the runway threshold, approximately 14 seconds after main landing gear touchdown. *See Figure 2.*

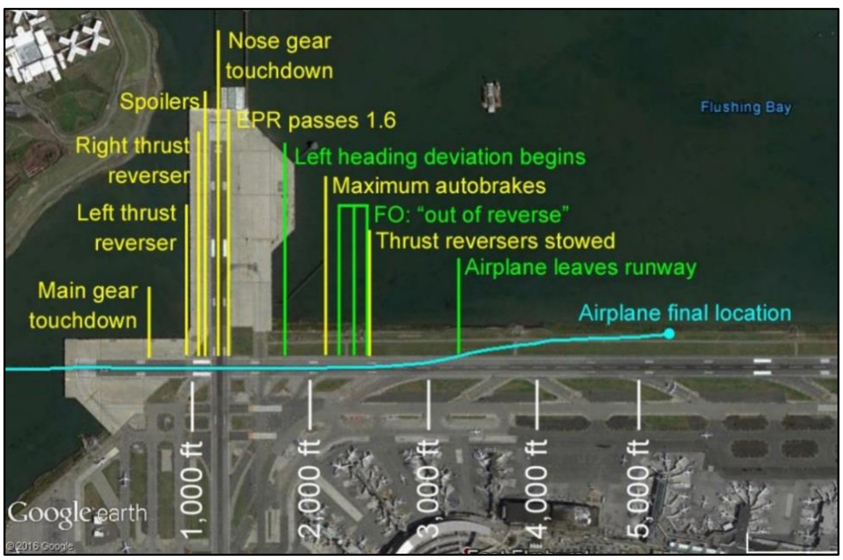

Figure 2: Aircraft ground path (NTSB).

As noted in the performance study, test data indicated that the rudder on the DC-9-80[ii] series aircraft have limited directional authority at airspeeds below 146 knots with reverse thrust EPR values above 1.6. Additionally, at airspeeds below 108 knots the rudder has limited directional authority with reverse thrust EPR values above 1.3. The high EPR values resulted in rudder blanking and the rudder's reduced effectiveness during the left yaw and heading deviation. The application of manual braking and nose wheel steering contributed to reducing the left yaw but were insufficient to correct the aircraft's path with the rudder blanked. The NTSB investigation was unable to determine the circumstances that contributed to the heading deviation.

Following the accident, data from the quick access recorder (QAR) from the accident aircraft and the prior landing aircraft, Flight 1526 a MD-88, were analyzed. The analysis revealed that EPR values above 1.6 were common, including during times of reported precipitation. *See Figure 3.* It was noted that none of the 80 recorded landings exhibited a significant deviation in heading or resulted in a runway excursion. Additionally, of all of the landings analyzed, the accident landing had the highest recorded EPR, as well as the shortest time to rise from 1.3 EPR to 1.6 EPR. The data review demonstrates that aircraft routinely experience reverse thrust above 1.3 EPR without degradation of lateral control; this indicates that the conditions of the runway at the time of touchdown likely contributed to the loss of directional control and inability to recover.

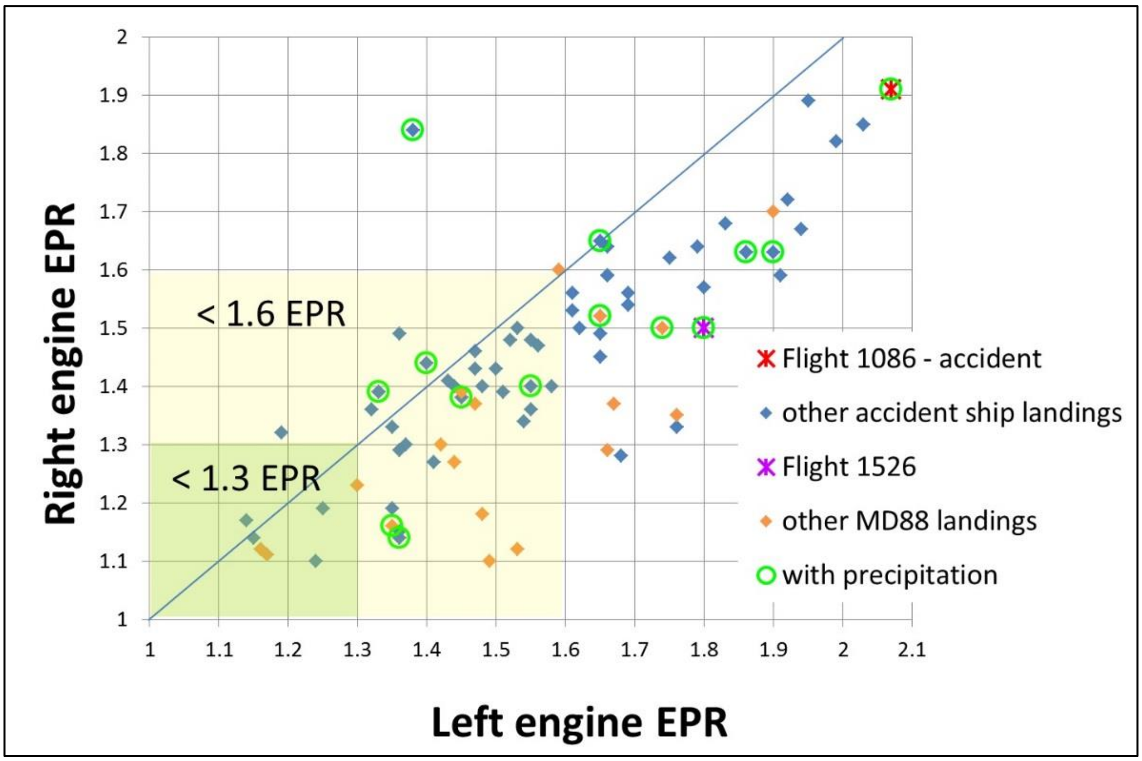

Figure 3: Scatterplot graph of recorded QAR data (NTSB).

Flight recorder data was used to estimate the wheel braking coefficients for the accident aircraft and the prior landing aircraft. The estimated wheel braking coefficient was determined to be approximately 0.16 or better[iii], which is less than GOOD. With the exception of one prior landing that reported braking action as MEDIUM at touchdown and POOR at rollout, the other landing aircraft reported GOOD braking action. This demonstrates the subjectivity of pilot braking action reports as it relates to actual runway friction assessments. Had the flight crew been provided with a more accurate runway condition assessment, they would have diverted, as discussed during approach, due to the need for GOOD or better braking action.

Airport Operations

The investigation produced a timeline of events that revealed the runway was last cleared at 1035 EST and the last NOTAM was issued at 0903 EST. The investigation uncovered that the 0738 EST NOTAM indicated that the runway had been chemically treated, even though it had not been. *See Figure 4.* The LGA operations manager stated in an interview that NOTAMs will only be issued when conditions change and a new NOTAM will not be issued after clearing operations, if the runway conditions are comparable to the conditions previously reported. This practice is not in accordance with FAA Advisory Circular (AC) 150/5200-30C.

Figure 4: Passenger photograph of the runway during landing.
Photograph copyright Jason Aspes.

Approximately 20 minutes after the accident, a request for a post event friction assessment was made but not accomplished by the Port Authority. Following the accident, it was requested that the Port Authority share friction testing results (Mu) during times of active precipitation. This request was denied by the Port Authority.

In an interview with LGA's chief operations supervisor, it was noted that LGA had CFME[iv] vehicles that were not used during snow removal operations. In regards to runway assessments and clearing, the NTSB referenced a January 20, 2016 email from the LGA aeronautical operations manager that states:

> LGA does not allow "snow to collect on the runway past the point of 'thin' or to the point [they] need to measure it. It is a visual assessment from the teams constantly monitoring the conditions on the field." With regard to specific "triggers" that require the beginning of plowing operations, he stated that the triggers were "braking action reports, visual inspection, weather forecast data, [and] surface temps."

According to FAA AC 150/5200-30C "Runway condition reports must be updated any time a change to the runway surface condition occurs." The AC notes that a change includes the application of chemicals or sand as well as runway clearing operations. Additionally, the AC states "airport operators should not allow airplane operations on runways after such activities until a new runway condition report is issued reflecting the current surface condition(s) of affected runways."

Oversight

The FAA airport certification inspector, who completed the annual airport inspection at LGA for the previous three years, was asked about information in AC 150/5200-30C. In response to a question noting that airports are required to comply with the AC, the inspector stated “an advisory circular is just that, advisory.” However, the APPLICATION section of the AC states:

> Certificated airports are required to follow the requirements of paragraphs 5-6 [Requirements For Runway Closures] and 5-7 [Continuous Monitoring] as of the effective date of this AC. In addition, all certificated airports must submit revised Snow and Ice Control Plans to the FAA no later than April 30, 2009 for approval. At that time, certificated airports will be required to comply with the remaining portions of this AC. The AC is advisory for non-certificated airports.

The inspector stated that in his personal opinion, the use of runway friction measuring equipment provides a useful tool for runway trending and that he was unaware that LGA does not use runway friction measuring devices during winter operations. The inspector noted that he was aware of an agreement with the air traffic control tower and the airport that states that the Port Authority “may” conduct runway friction assessments when necessary.

Probable Cause

The NTSB determined that the probable cause of this accident was “the captain’s inability to maintain directional control of the airplane due to his application of excessive reverse thrust, which degraded the effectiveness of the rudder in controlling the airplane’s heading.” The NTSB noted that “Contributing to the accident were the captain’s (1) situational stress resulting from his concern about stopping performance and (2) attentional limitations due to the high workload during the landing, which prevented him from immediately recognizing the use of excessive reverse thrust.”

Similar Event

Due to the design of the thrust reversers on the DC-9-80 series aircraft, the fleet has experienced several accidents where rudder blanking was a factor. One such event is an accident involving a McDonnell Douglas Corporation DC-9-80 in Yuma, AZ on June 19, 1980. In that event, the aircraft departed the right side of the runway while attempting a simulated hydraulic system inoperative landing. The NTSB determined the probable cause of the accident to be the “Inadequate procedures established for certification test flight, and the pilot's mismanagement of thrust following the initial loss of directional control.” During the investigation, the NTSB conducted flight tests and high speed taxis at 90 and 140 knots, to determine directional controllability with various levels of forward and reverse thrust. The NTSB stated “the flight test data showed that at 1.6 EPR symmetrical reverse thrust and at 109 KIAS, the powered rudder control effectiveness as zero.” *See Table 1.*

Engine Thrust Setting	Maximum Rudder Effectiveness Available (percent)*
Forward idle	100
Reverse Idle	65
1.3 EPR (Reverse)	25
1.6 EPR (Reverse)	minimal
*Rudder effectiveness also decreases with decreasing speed	

Table 1: DC-9-80 Rudder Effectiveness Availability (NTSB AAR81-16).

The investigation resulted in the NTSB issuing 11 recommendations, which included a recommendation to incorporate DC-9-80 rudder blanking and rudder effectiveness information into training manuals and curriculums. This recommendation was closed with acceptable action in 1984. Although rudder blanking information has been incorporated into training manuals and curriculums, the detailed rudder effectiveness availability information identified in the Yuma, AZ investigation has not been incorporated.

Incident Prevention

Boeing

Following the 1980 accident, rudder blanking information was disseminated via several methods including a February 15, 1996 Boeing All Operators Letter. This letter discussed MD-80 landing characteristics on wet or slippery runways. The letter noted that the reverse thrust buckets were canted slightly to reduce foreign object damage (FOD). The angle of the thrust reversers resulted in a disruption of airflow across the rudder when a reverse thrust setting of above approximately 1.3 EPR is used.

In an effort to develop a technological solution to prevent excessive reverse thrust, Boeing issued Service Bulletin MD80-78-068 on May 29, 1996. The bulletin implemented an improved thrust reverser cam support assembly. The new assembly provided the flight crew with a throttle lever detent for 1.3 EPR. Due to reports of excessive EPR split with the new assembly, the bulletin was rescinded by Service Bulletin MD80-78-070 on May 29, 1997.

On November 05, 2002, Boeing issued a Flight Operations Bulletin to all MD-80 operators stating that 1.3 EPR should be the maximum reverse thrust power under wet or slippery runway conditions.

Delta Air Lines

Following the accident in LGA, Delta conducted a Safety Management System (SMS) Safety Risk Assessment (SRA) to review reverse thrust usage on the MD-88. After completion of the SRA, a decision was made to limit reverse thrust to 1.3 EPR on dry runways (formerly 1.6). When landing on non-dry runways, flight crew initially select idle reverse thrust and after reverse thrust symmetry is verified with the aircraft aligned with the runway track, flight crews may gradually increase reverse thrust to no greater than 1.3 EPR.

Delta is continuing its participation in two demonstration studies of aircraft-based technology that have the potential of becoming runway friction assessment tools for next generation contaminated runway guidance. One such tool is Aviation Safety Technologies' (AST) SAFELAND system[v], which uses the aircraft's systems to report "true aircraft runway surface characteristics, true aircraft runway surface characteristics, true braking friction, cornering friction and tire and brake wear." The system does this by monitoring and measuring multiple aircraft parameters that includes spoilers, flaps, hydraulic and mechanical braking, accelerometers, and atmospheric conditions. The SAFELAND system has been placed on Delta's A319/320 and B737-700/800/900ER fleets. Delta is also participating with Zodiac Aerospace[vi] to test their Braking Action Safety System (BASS).

Through previous internal investigations into runway excursion events, on all fleets, during winter conditions and several visits with airport management at northern tier airports, a Special Winter Operations Airport (SWOA) program was established in 2005. Flight Safety introduced the SWOA program to mitigate the risks associated with the difficulty in standardizing runway treatment, clearing, and friction testing, as well as addressing environmental factors, which increase an aircraft's risk of runway excursion during winter conditions. Additionally, the program was designed to assist airports in upgrading snow plans, equipment, and facilities. SWOA airports are identified through a matrix that accounts for several elements including: incident history, friction testing equipment used, vertical guidance availability, runway lighting, runway length, field elevation, and surrounding terrain. Airports that have been identified through the SWOA program will be scheduled for a bi-annual visit to foster conversations to enact changes to improve safety. SWOA airports are also subject to operating restrictions when frozen precipitation is falling and accumulating or the runway is contaminated with frozen precipitation.

Industry

Following a 2005 runway excursion at Midway Airport in Chicago, IL, the FAA formed the Takeoff and Landing Performance Assessment (TALPA) Aviation Rulemaking Committee (ARC) to reduce the risk of runway excursions. The committee developed recommendations for airport authorities determine runway conditions and for aircraft operators to determine required stopping distances. The FAA used the TALPA ARC's recommendations to develop new methodologies which were implemented on October 01, 2016. As a part of the new methodologies, the FAA has implemented the use of a Runway Condition

Assessment Matrix (RCAM) which will be used to determine a numerical Runway Condition Code (RwyCC). The use of RwyCC will replace runway friction assessments (Mu) when conducting landing distance assessments. Additional implemented methodologies will align processes with International Civil Aviation Organization (ICAO) standards.

The ICAO Friction Task Force has also developed runway assessment and reporting processes based on the TALPA ARC recommendations. These processes also use runway conditions that are coded in a matrix to provide runway performance information.

Conclusion

The flight crew identified the need for a braking action of GOOD or better in order to land, which they received from pilot reports from prior landing aircraft. In addition to the pilot reports, the LGA NOTAMs lead the flight crew to anticipate a runway condition that did not exist. The actual runway condition was snow covered and not chemically treated with an estimated braking coefficient that was less than GOOD at 0.16 or better. After touchdown, the aircraft experienced a left yaw and due to excessive reverse thrust above 1.3, the flight crew was unable to recover before departing the paved surface and striking a sea wall.

Although the DC-9-80 series aircraft have unique landing characteristics on wet or slippery runways and are more susceptible to rudder blanking, the industry continues to experience excursions on all types of aircraft. With new aircraft becoming ever more sophisticated, the industry has an opportunity to develop reliable and repeatable methods to generate braking action reports that do not rely on the subjectivity of flight crews. As safety professionals, we must champion for standardization in airport procedures and objective methods of determining runway friction to mitigate the risk of future runway excursions on wet or slippery runways.

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[i] Additional details for this event can be found at http://www.ntsb.gov/.

[ii] DC-9-80 series aircraft are derivatives of the DC-9 and include the MD-81, MD-82, MD-83, and MD-87, and MD-88.

[iii] A wheel braking coefficient of 0.16 is within the range for MEDIUM pilot-reported braking action as defined by FAA AC 25-32, dated December 22, 2015, page 14.

[iv] CFME is defined as continuous friction measuring equipment.

[v] http://www.aviationsafetytechnologies.com/safeland/

[vi] http://www.zodiacaerospace.com/en