Aviation Investigation Final Report

Location:	Chicago, Illinois	**Incident Number:**	DCA11IA047
Date & Time:	April 26, 2011, 13:33 Local	**Registration:**	N799SW
Aircraft:	Boeing 737-7Q8	**Aircraft Damage:**	Minor
Defining Event:	Landing area overshoot	**Injuries:**	139 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

The flight was routine until nearing the Chicago terminal area, where delays due to traffic, weather, and conflicting approaches with O'Hare International Airport resulted in an air traffic controller instructing the flight crew to expect to hold. Shortly afterward, the controller advised the crew that aircraft capable of required navigation performance (RNP) approaches to runway 13C would be accepted to MDW. The flight crewmembers mistakenly loaded and briefed a different procedure, the area navigation (RNAV) global positioning system (GPS) approach, before entering the holding pattern. While in the holding pattern, the flight crew performed a landing distance assessment using the onboard performance computer (OPC). The calculation results showed sufficient runway length for the landing in accordance with the flight manual procedures. Data from the cockpit voice recorder and the OPC indicate that the crew performed the assessment correctly.

After receiving air traffic control (ATC) clearance to leave the holding pattern and begin the approach to MDW, the flight crewmembers discussed confusion about the approach instruction, likely because they had loaded and briefed the wrong approach procedure. The flight crew then identified the proper approach procedure chart. The crew subsequently reprogrammed the flight management system for the correct approach and amended some of the procedure crossing altitudes in order to follow ATC instructions. These activities at this point in the approach resulted in extra workload for the flight crew.

Later, as flight 1919 neared the runway, the flight crew set flaps to 15. The flight crew of a preceding Southwest Airlines 737 arrival reported "fair" braking action on runway 13C to ATC. The air traffic controller did not advise the flight 1919 crew of the braking action report

transmitted by the previous arrival; however, the incident crew overheard the report and correctly recalculated the landing distance assessment, which again indicated sufficient runway length available. The incident crew also set the airplane autobrakes appropriately for the conditions.

In addition to discussion regarding the approach procedure automation, the crew had additional operational distractions in the final minutes of the approach. These included a momentary flap overspeed as the first officer attempted to set flaps to 25, assessment of a rain shower passing over the airport, and incorrect settings for minimum altitude reminders. The delay in setting flaps to 25 as the first officer waited for airspeed to decay occurred about the same time that the crew normally should have been executing the Before Landing checklist, which includes the item “speedbrake—armed.” No mention of speedbrakes or the Before Landing checklist is heard on the cockpit voice recording, and data from the flight data recorder (FDR) indicate that the speedbrakes were not armed.

The airplane touched down within 500 feet of the runway threshold. After touchdown, the captain perceived a lack of braking effectiveness and quickly applied full manual brakes. Speedbrakes did not deploy upon touchdown, nor were thrust reversers deployed. About 16 seconds after touchdown, thrust reversers were manually deployed, which also resulted in speedbrake deployment per system design, when the airplane had about 1,500 feet of runway remaining. As the airplane neared the end of the pavement, the captain attempted to turn onto the connecting taxiway but was unable. The airplane struck a taxiway light and rolled about 200 feet into the grass.

FDR data and component examination revealed that all airplane systems operated as expected. The automatic speedbrakes were not armed and, therefore, would not deploy upon touchdown without crew action. Extending the speedbrakes after landing increases aerodynamic drag and reduces lift, which increases the load applied to the main gear tires and makes the wheel brakes more effective. A lack of speedbrake deployment results in severely degraded stopping ability. According to the flight operations manual, braking effectiveness is reduced by as much as 60 percent. The flight crew’s delay in applying reverse thrust also contributed to the amount of runway used.

Simulation studies concluded that the airplane would have stopped with about 900 feet of runway remaining if the speedbrakes had been deployed at touchdown (without reverse thrust) or with about 1,950 feet remaining if both speedbrakes and reverse thrust had been deployed at touchdown, per standard procedures. The calculated braking coefficient of the incident airplane was consistent with a “fair” braking action report, as given by the preceding Southwest

Airlines 737 arrival. The braking coefficient is also in accordance with the OPC calculations.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The flight crew's delayed deployment of the speedbrakes and thrust reversers, resulting in insufficient runway remaining to bring the airplane to a stop.

Contributing to the delay in deployment of these stopping devices was the flight crew's inadequate monitoring of the airplane's configuration after touchdown, likely as a result of being distracted by a perceived lack of wheel braking effectiveness.

Contributing to the incident was the flight crew's omission of the Before Landing checklist, which includes an item to verify speedbrake arming before touchdown, as a result of workload and operational distractions during the approach phase of flight.

Findings

Personnel issues	Use of equip/system - Flight crew
Personnel issues	Identification/recognition - Flight crew
Personnel issues	Monitoring equip/instruments - Flight crew
Personnel issues	Use of checklist - Flight crew
Aircraft	Drag control system - Incorrect use/operation
Aircraft	Thrust reverser - Incorrect use/operation
Personnel issues	Delayed action - Flight crew

Factual Information

History of Flight

Landing-landing roll	Landing area overshoot (Defining event)

HISTORY OF FLIGHT

On April 26, 2011, about 1333 central daylight time (CDT), a Boeing 737-7Q8, registration N799SW, operated by Southwest Airlines as flight 1919, exited the left side of the pavement near the departure end of runway 13C after landing at Chicago Midway International Airport (MDW), Chicago, Illinois. The flight was a regularly scheduled passenger flight from Denver International Airport, Denver Colorado, operating under the provisions of 14 Code of Federal Regulations (CFR) Part 121. There were no injuries to the 134 passengers, including 5 lap-held children, or the 5 crewmembers. The airplane sustained minor damage to the left and right engines and the inboard aft flaps.

The crew and operator reported the flight to be routine until nearing the Chicago terminal area. About 1232, the Chicago Approach Control (C90) air traffic controller advised of delays into the Chicago area and that arrivals would be using required navigation performance (RNP) approaches. The crew began to brief the area navigation (RNAV) global positioning system (GPS) Z approach, instead of the RNP approach, and discussed how to set up the flight management system (FMS). At 1238, the flight crew performed the descent checklist, which included setting and cross-checking altimeters and bugs, setting the reference and target airspeeds (to 129 and 145 knots, respectively). The crewmembers stated that they selected autobrakes to “MAX” as indicated by the onboard performance computer (OPC) Landing Output and in accordance with Southwest Airlines Flight Operations Manual (FOM). About 1240, C90 instructed the flight to hold at the SMARS waypoint due to traffic congestion and conflicting traffic patterns with Chicago O’Hare International Airport. While entering and during the hold, the crew discussed fuel and diversion options.

About 1256, the crew received ATIS (automated terminal information service) Oscar, observation time 1251 CDT, wind 190 degrees at 16 knots, gusts to 23 knots, visibility 6 statute miles in light rain and mist. Clouds at 800 feet scattered, ceiling 1,400 feet broken, 2,200 feet overcast, temperature 16ºC, dew point 14ºC, altimeter setting 29.40 inches of mercury. The recording stated that the instrument landing system (ILS) for runway 13C was in use, landing and departing runway 13 (sic), departing runway 22L. The recording also included numerous NOTAMs not pertinent to the incident.

Following the receipt of the weather, the crew began performing landing distance calculations using the OPC. The initial entry included a landing weight of 127,000 pounds, wet runway with good braking action, and thrust reverse at detent 2. According to the Southwest Flight

Reference Manual (FRM) and FOM, the OPC approximate stopping margin calculation was based on minimum, medium, and maximum braking and corresponded to three different autobrake settings (2, 3, and MAX). The FOM also provided guidance on approximating the autobrake actions when using manual braking. Each stop margin calculation included a 1,500-foot air distance from threshold to touchdown and an extra 15 percent distance factor. Stop margin was the distance remaining after the aircraft comes to a complete stop, measured from the nose gear to the end of the available runway.

The landing output for maximum braking (autobrake MAX) produced a positive margin of 690 feet. Entering minimum (autobrake 2) or medium braking (autobrake 3) did not provide a positive stopping margin. The crew also performed another calculation with the same inputs except for a 126,000-pound landing weight, and the margin with maximum braking was 720 feet.

About 1314, C90 began accepting RNP-capable aircraft destined to MDW. The incident flight was third in the sequence, following another Southwest 737 and a general aviation Citation jet.

At 1319, the crew reported to C90 that they were level at 6,000 feet, indicating an airspeed of 210 knots and had received information "Oscar." The controller advised the crew to expect the RNAV (RNP) Y 13C approach and to slow to 170 knots for traffic sequencing. The controller subsequently cleared the flight direct to the Joliet waypoint (geographically coincident with the Joliet very high frequency omnirange (VOR) navigation aid) and stated "at Joliet intercept the final approach course." The crew acknowledged the instruction but discussed some confusion about it, likely because Joliet does not appear on the RNAV GPS Z approach chart; rather, it is the RNAV (RNP) Y 13C initial approach fix, beginning the initial approach segment, which had a track of approximately 90 degrees to the final approach course. About 1320, after a brief discussion, the crew set flaps to "2" and then further discussed the controller's instructions. The crew then identified the proper approach procedure chart and reconciled the instructions with the chart. C90 instructed the crew to descend to 2,500 feet after completing the speed reduction to 170 knots. The RNAV (RNP) Y 13C chart noted a minimum altitude of 4,000 feet after Joliet and a mandatory crossing altitude of 4,000 feet at TOYUL waypoint. The crew acknowledged the controller's instruction and began briefing and configuring the FMS for the RNAV (RNP) Y 13C procedure.

About 1325, the preceding Southwest 737 landed, which was the first arrival on runway 13C in the previous 25 minutes. At 1326:36, the controller stated "Southwest 1919, three miles from TOYUL, cleared for RNAV RNP Y runway one three center approach Midway, maintain 170 knots." The crew acknowledged and discussed the weather radar display and the nearby rain showers.

At 1328:37, C90 instructed the incident flight to maintain 170 knots until JUPIR waypoint and to contact the MDW airport traffic control tower local controller (LC). The crew acknowledged and began to monitor the LC radio frequency. At this time, the crew was discussing symbology and information on the flight instrument displays regarding the approach

procedure.

At 1329:26, the crew selected landing gear down and flaps 15. The preceding Southwest crew was taxiing clear of the runway and reported the runway was wet with fair braking action. LC relayed the braking report to the pilot of the Citation jet. At 1330:22, the LC controller was relieved by another controller, and the braking report was not included in the position relief briefing or passed to the incident crew. However, the incident crew overheard the runway condition report and made new entries into the OPC. Using the wet runway, fair braking action input, with a 126,000-pound landing weight and maximum reverse thrust and braking, the OPC calculated a landing with 210 feet of margin. About the same time, the crew attempted to set flaps to 25 but noted the airspeed was too high for that setting. Shortly after, the crew selected flaps 30 then, almost immediately, flaps 40. The Southwest Airlines B737-700 Normal Checklist "Before Landing" section reads: "Speedbrake - Armed, Green Light; Landing gear- Down, 3 Green; Flaps – [appropriate setting], Green Light." Neither the phrase "before landing checklist" nor any mention of "speedbrake" were heard on the cockpit voice recording. The Southwest Airlines FOM stated the before landing checklist should be completed no later than 1,000 feet above touchdown zone elevation and after landing flaps are set.

At 1330:44, the incident crew reported passing the JUPIR waypoint inbound and asked LC the direction in which a rain shower was moving. LC responded with an advisory about the traffic they were to follow and landing clearance for runway 13C and advised that the wind was 210 degrees at 9 knots and that the rain was moving to the east-northeast. The crew acknowledged.

Beginning about 1331, the crew further discussed the approach procedure; at 1331:37, the captain stated that the airplane was approaching minimums, which was followed by discussion with the first officer about the altimeter display. This discussion ended with the first officer stating, "I'd set mine wrong." At this point, the airplane was still about 1,000 feet above the runway (about 1,454 mean sea level). Decision altitude for the approach was 1,065 feet above mean sea level, or 454 feet above the runway touchdown zone.

At 1333:05, the airplane touched down on runway 13C at an airspeed of 136 knots and a groundspeed of 143 knots. The touchdown occurred within 500 feet of the displaced arrival threshold of the runway, leaving approximately 5,600 feet of runway available for rollout. At the same time, LC advised a following airplane that the wind was from 220 degrees at 10 knots, gusting to 17 knots.

Flight data recorder (FDR) information shows that, upon touchdown, the autobrakes indicated "applied" and both main landing gear brake pressures began to increase. After about 1 second, the autobrake parameter indicated "No Auto Brk" while the pilot commanded brake pressure continued to increase (without any fluctuations) up to about 3,000 pounds per square inch (psi), where it remained for the rest of the landing. The crewmembers reported that they applied maximum manual braking shortly after touchdown because of a perceived lack of braking effectiveness; cockpit voice recorder (CVR) evidence is consistent with this report.

High manual brake pressure will release the autobrakes and disarm the autobrake system per system design. Anti-skid braking capability is not affected.

About 8 seconds after touchdown, the captain stated “I got no brakes”, and the first officer advised he was also applying brakes. About 15 seconds after touchdown, one of the pilots commented about the power, and, about 10 seconds later, a sound similar to increasing reverse thrust is heard.

FDR data indicate that throughout the final approach, touchdown, and initial rollout, the speedbrake handle remained at 0 degrees (not armed) and the speedbrake “armed” light was not illuminated. The speedbrake handle remained in its down position upon touchdown and for the first 16 seconds of the landing rollout. Southwest FOM guidance states: “On initial landing roll, braking effectiveness is reduced by as much as 60 percent without speedbrake deployment.”

FDR and video data also indicate that the spoilers did not deploy until approximately 17 seconds after touchdown, when the airplane was about 4,600 feet beyond the runway displaced threshold. There are four flight and two ground spoilers on each wing, controlled by the speedbrake system, and normally all the spoilers deploy upon touchdown.

FDR and system data indicate that between 15 and 20 seconds after touchdown, the reverse thrust levers were moved to deploy the thrust reversers, which also caused the spoilers to automatically deploy. About 16 seconds after touchdown, the value for the left throttle resolver angle (TRA) increased from its idle position up to a value slightly less than 44 degrees, indicating that this thrust lever had moved forward of its idle position; the value for the right TRA began decreasing from 36 degrees to 24 degrees, indicating that this thrust lever remained in idle and its reverse lever had been activated towards idle reverse. The speedbrake handle began to extend, the speedbrake “armed” light illuminated, and the spoilers began to deploy. For a short period, the value for the left TRA increased from a value of about 44 degrees up to a value slightly greater than 50 degrees. According to the speedbrake system logic, if the value for any TRA exceeds 44 degrees, the auto speedbrake system will command the spoiler actuators to retract. At this time, during the speedbrake handle extension, the rate of the handle movement decreased, at a handle position of about 20 degrees. As the left TRA decreased from about 50 degrees to a value slightly less than 24 degrees, the data indicate that the speedbrake handle was fully extended, the speedbrake “armed” light remained illuminated, and the spoilers were fully deployed. By this time, about 1333:25, both reverser levers were also moving toward the maximum reverse position and engine power began to increase.

At the time the spoilers deployed, the airplane had travelled about 4,150 feet from the touchdown point. About 3 seconds later, the thrust reversers indicated deployed, and the airplane was travelling about 92 knots groundspeed at 4,350 feet from touchdown, with about 1,259 feet of runway remaining. The engines spooled up to full power by the time the airplane had 250 feet of runway remaining and had slowed to 55 knots. The airplane heading began to

move slightly left of runway heading, and, by 1333:34, the heading had diverged by more than 10 degrees and continued left to about 35 degrees left of runway heading. The captain stated that he attempted to turn the airplane onto the last taxiway on the left side of the runway, but the airplane was still moving too fast to make the turn. At 1333:35, a rumbling sound consistent with the airplane leaving the pavement was heard on the CVR. The airplane left the paved surface at about 30 knots groundspeed, with thrust reversers fully deployed and engine power at or near maximum. Spoilers were deployed and pilot-commanded brake pressure indicated the maximum value of 3,000 psi.

The reversers were stowed, power was reduced, and the speedbrake handle retracted as the airplane decelerated in the grass through about 10 to 15 knots. Commanded brake pressure remained at 3,000 psi until the end of the data. By 1333:44, the airplane had come to a stop, about 180 feet beyond and left of the runway end in a soft grassy area, north of the engineered materials arresting system (EMAS).

At 1333:48, the captain made a cabin announcement advising the passengers to remain in their seats. At 1334:07, the crew ascertained there was no fire, and advised the passengers that stairs would be on the way to allow them to deplane. At 1334:00, the pilot advised LC that the airplane was in the grass. LC acknowledged and advised him that the emergency vehicles were on the way. Between 1334:30 and 1339:00, the crew discussed the airplane configuration, the stairs and passenger egress, and further discussion about configuration and landing distance. Another OPC calculation was performed, identical to the previous entry.

The passengers and crew exited the airplane via airstairs and were bused to the terminal.

INJURIES TO PERSONS

There were no injuries to the 134 passengers, including 5 lap-held children, or the 5 crewmembers.

DAMAGE TO AIRCRAFT

The right engine sustained damage from ingesting a taxiway light, and the thrust reverser and inlet cowls were damaged. Two fan blades of the left engine were bent. The left and right inboard aft flaps were damaged. The damage did not meet the 49 CFR Part 830 definition of “substantial.”

OTHER DAMAGE

One taxiway light was ingested by the right engine.

PERSONNEL INFORMATION

The captain, age 50, was hired by Southwest Airlines in January 1993. He upgraded to captain

about 3 years later and, at the time of the incident, he also held the position of check airman. He was based at Baltimore, Maryland, and earned his commercial and instrument pilot certificates before joining the U.S. Air Force, where he was an instructor pilot and flew C130s.

The captain reported approximately 10,500 hours total time, including about 7,000 hours as pilot-in-command and 7,000 hours in the B737 (which included about 5,000 hours as pilot-in-command).

There were no records or reports of any previous aviation incidents or accidents involving the captain. A search of the National Driver Register found no record of driver's license suspension or revocation.

The captain held a valid Federal Aviation Administration (FAA) airline transport pilot (ATP) certificate with type ratings for L382 and B737, and a current FAA first-class medical certificate. There were no testing or checking failures in the FAA records. Training and proficiency checks were current, and the company reported that the captain had no unsatisfactory proficiency checks or line checks.

The first officer, age 50, was hired by Southwest Airlines in July 2002. He was also based at Baltimore. He flew various general-aviation-type operations in the 1980s and 90s, and, from 1997 to September 2001, he flew regional jets for Midway Airlines. He reported about 17,000 hours total time, including an estimated 7,000 hours of B737 second-in-command time. There were no records or reports of any previous aviation incidents or accidents involving the first officer. A search of the National Driver Register found no record of driver's license suspension or revocation. The first officer held a valid FAA ATP certificate with type ratings for BE-1900, BE-300, CL-65, and B737, and a current first-class medical certificate.

The first officer's training and proficiency checks were current. FAA records indicate that he received a notice of disapproval on September 11, 1999, when he failed a practical test for a CL-65 type rating to be added to his ATP certificate. He was unsatisfactory in the area of ground operations. He was retested on October 21, 1999, and passed. The first officer reported that other than the test failure while at Midway Airlines, he had no training or checking difficulties in his career before or after this event.

On the day of the incident, the captain and first officer had flown two legs before the event flight. They reported waking early (0315 and 0405 eastern daylight time respectively) for the first flight from Baltimore to MDW, which had a report time of 0515 eastern daylight time. They then flew from MDW to Denver and departed Denver about 1105 mountain daylight time on the incident flight.

AIRCRAFT INFORMATION

The incident airplane, N799SW, manufacturer serial number 28209, ship number 799, is a Boeing 737-7Q8 equipped with General Electric CFM56-7B24 engines. The airplane had

approximately 45,577 hours total time on the airframe at the time of the incident. Recorded data and airline records indicated no relevant maintenance issues with the airplane. At the time of the incident, the estimated landing weight was 124,665 pounds.

Auto Speedbrake Control System

The auto speedbrake control system is designed to automatically drive the speedbrake handle to its full “up” position (48 degrees) to deploy all of the spoilers (four flight and two ground spoilers on each wing) upon landing.

There are two methods in which the system can automatically drive the speedbrake handle to its full-up position. The first method requires the pilot to raise the speedbrake handle out of its down and locked detent (0 degrees) and move it aft to its “armed” detent (4 degrees) before landing. Upon touchdown, the auto speedbrake system will automatically drive the speedbrake handle from its “armed” detent to its full “up” position to deploy all of the spoilers. The second method was designed to drive the speedbrake handle out of its down detent by moving either reverse thrust lever to its “idle reverse” position (TRA = 24 degrees) during a rejected takeoff when the speedbrake handle is in its down detent.

When the speedbrake handle is in its “armed” detent, the speedbrake “armed” light will illuminate, providing the crew with a visual indication that the automatic operation of the speedbrake system armed correctly. This will occur when the speedbrake handle is in the “armed” detent or either thrust lever is in reverse, and all of the following conditions are satisfied: 1) One or more antiskid channel is functional, 2) the auto speedbrake actuator is in the fully retracted position, and 3) there is not a disagreement with the wheel speeds and the air/ground signals. Upon touchdown, the auto speedbrake system will automatically drive the speedbrake handle from its “armed” position to its full “up” position to deploy all of the spoilers when the correct logic conditions occur.

Autobrake Control System

The hydraulic brake system is used to provide a means to slow down and/or stop the airplane after landing touchdown and during taxi operations. Brakes installed in each of the main landing gear wheels are actuated hydraulically by manual brake pedal movement or automatically through the autobrake control system. In the manual mode of operation, the two brakes on the left gear are operated by the pilot’s left pedals and the two brakes on the right gear are operated by the pilot’s right pedals. The captain’s and first officer’s brake pedals are joined together by a linkage so that braking force will be the combined force applied to the pedals by both pilots. The antiskid system controls the metered brake pressure from the hydraulic brake system or the autobrake pressure from the autobrake system to prevent wheel skid. This is designed to provide the maximum wheel braking efficiency in any runway condition. When armed, the autobrake system automatically applies the brakes after landing, to slow the airplane at a target deceleration rate selected by the pilots before landing.

The autobrake system will disarm and release brake pressure when the autobrakes selector switch is selected to “OFF” or to an invalid switch position, if either manual metered brake pressure switch indicates high, if the speedbrake lever is moved to the down position after having been armed, if either thrust lever is advanced, or if a system fault is detected. According to the flight crewmembers, they applied the manual brakes almost immediately upon touchdown.

METEOROLOGICAL INFORMATION

WSR-88D and terminal Doppler weather radar images and lightning data depicted a thunderstorm moving eastward over the incident site 5 to 10 minutes before the airplane touched down, with the thunderstorm diminishing to light to moderate echoes at the approximate time of the incident.

The MDW 1251 observation was included in ATIS information “Oscar” (see History of Flight). The surface observation at 1328 CDT, reported wind from 220 degrees at 10 knots with gusts to 17 knots, visibility 1 and 1/2 miles, moderate rain and mist, scattered clouds at 900 feet, a broken ceiling of cumulonimbus clouds at 1,500 feet, overcast skies at 3,400 feet, temperature of 16 degrees C, dew point temperature of 14 degrees C, and an altimeter setting of 29.41 inches of mercury. At 1344, the observation reported wind from 210 degrees at 12 knots with gusts to 21 knots, visibility 7 miles, light rain, few clouds at 900 feet, a broken ceiling of cumulonimbus clouds at 1,500 feet, overcast skies at 3,400 feet, temperature of 16 degrees C, dew point temperature of 14 degrees C, and an altimeter setting of 29.41 inches of mercury.

Automated surface observing system (ASOS) 1-minute raw wind data was obtained for 1333 with two separate magnitudes and wind directions. The system reported the 2 minute average wind from 218 degrees at 12 knots, and a 5-second maximum average wind from 231 degrees at 16 knots. Heavy rain was also reported, with a total of 0.11 inch of precipitation falling over the 11 minutes preceding the incident.

A SIGMET valid at the time of the incident advised of a 25-mile-wide line of thunderstorms bounded from 50 miles north-northeast of Decatur, Illinois, to 25 miles southwest of Decatur that was moving from 230 degrees at 35 knots with thunderstorm tops to flight level (FL) 400.

A center weather service unit advisory issued at 1300 CDT valid through 1400 CDT forecasted that an area of scattered showers and thunderstorms would continue to develop around the incident site with cloud tops to FL250 to FL350. The showers and thunderstorms were forecasted to move from 230 degrees at 45 knots.

The National Weather Service Terminal Aerodrome Forecast for the incident location was issued at 1240 CDT and was valid for a 24-hour period beginning at 1300 CDT. The forecast expected wind from 210 degrees at 17 knots with gusts to 28 knots, 6 miles visibility with light rain showers, scattered clouds at 1,500 feet, a broken ceiling at 2,500 feet, overcast skies at 3,500 feet. Temporary conditions of 3 miles visibility and moderate rain showers, scattered

clouds at 1,500 feet, and an overcast ceiling of cumulonimbus clouds at 2,500 feet were expected between 1300 CDT and 1700 CDT.

AIDS TO NAVIGATION

RNP capability allows an aircraft to fly a specific path between two or more three dimensionally-defined points in space, including curved paths and use of vertical angles or specific altitude constraints to define a desired vertical path. RNP procedures are developed to enhance airport access in demanding environments. Southwest Airlines received approval for RNP procedures in April 2010 and initiated use of the procedures in line operations in January 2011.

The RNAV (RNP) Y RWY 13C approach began over the Joliet VOR, approximately 25 miles southwest of MDW. The initial and intermediate approach segments proceeded to the northeast, with prescribed altitude constraints at 4,000; 2,500; and 2,000 feet before describing a curved path to the southeast passing JUPIR waypoint. A vertical glidepath began at NIDEE waypoint, which was the final approach fix. The course continued to curve to the right and aligned the aircraft with the runway at DULTE waypoint, 3 miles from touchdown. Approach minimums were specified as a decision altitude of 1,065 feet above mean sea level (454 feet above threshold) and 1 1/2 miles visibility.

COMMUNICATIONS

No communications problems were noted at any time during the incident.

FAA Order 7110.65, “Air Traffic Control,” and the Aeronautical Information Manual define braking action advisories as follows:

When tower controllers have received runway braking action reports which include the terms ‘fair,’ ‘poor,’ or ‘nil,’ or whenever weather conditions are conducive to deteriorating or rapidly changing runway braking conditions, the tower will include on the ATIS broadcast the statement, ‘Braking action advisories are in effect’ on the ATIS broadcast. During the time braking action advisories are in effect, ATC will issue the latest braking action report for the runway in use to each arriving and departing aircraft. Pilots should be prepared for deteriorating braking conditions and should request current runway condition information if not volunteered by controllers. Pilots should also be prepared to provide a descriptive runway condition report to controllers after landing.

AERODROME INFORMATION

MDW is located 9 miles southwest of Chicago, Illinois, with numerous obstacles, buildings, and roads immediately adjacent to the field. At the time of the incident, the airport handled approximately 670 aircraft per day, consisting of about 75 percent airline traffic, 16 percent transient general aviation traffic (largely business aircraft) and 8 percent air taxi aircraft.

Runway 13C is 6,522 feet long and 150 feet wide with a displaced threshold of 463 feet, leaving 6,059 feet landing distance available. Touchdown zone elevation is 611 feet. The runway is concrete and grooved and was reported as wet with fair braking action by a 737 crew just before the incident. A 190–foot-long by 170 foot–wide EMAS barrier is located at the departure end of runway 13C. The runway is served by a four-light precision approach path indicator system with a 3-degree glidepath on the right side of the runway and a lead-in light system. Visual inspections of runway 13/31C at MDW, conducted in July 2010 and August 2011 during FAA airport certification annual inspections, identified no anomalies pertaining to the runway.

FLIGHT RECORDERS

The CVR, an Allied Signal 980-6022-001, serial number 0777, was a solid-state CVR that recorded 2 hours of digital cockpit audio. The recorder was received with no heat or structural damage and the audio information was extracted from the recorder normally, without difficulty. The quality of the audio was characterized as good to excellent. A CVR group was convened and created a transcript. Timing on the transcript was established by correlating the CVR events to common events on the FDR.

The FDR, a Honeywell SSFDR, Model 980-4700, serial number 4425, records a minimum of 25 hours of airplane flight information in a digital format using solid-state flash memory as the recording medium. The recorder was received in good condition and the data were extracted normally from the recorder. Correlation of the FDR data to the event local time, CDT, was established by using the FDR-recorded Greenwich mean time (GMT) hour, minute, and second time parameters then applying an additional 5-hour offset to change GMT to local CDT time.

WRECKAGE AND IMPACT INFORMATION

N/A

MEDICAL AND PATHOLOGICAL INFORMATION

On April 26, 2011, the captain and first officer complied with a company request to submit to drug and alcohol screening tests. Results of these tests were negative for alcohol and major drugs of abuse.

FIRE

None

SURVIVAL ASPECTS

No emergency evacuation was conducted. All passengers and crew deplaned via airstairs.

TESTS AND RESEARCH

An airplane performance study was completed by the NTSB with technical support from Boeing Aircraft Company and Southwest Airlines. Data from the study is incorporated in the History of Flight and Aircraft Information sections of this report.

Boeing performed a series of 737-700 simulations to determine the aircraft's braking performance for the incident conditions. The calculated airplane braking coefficient during the incident runway ground roll varied with aircraft speed and runway surface conditions for an average value of 0.15. The airplane braking coefficient is the ratio of the frictional retarding force on the tires (including rolling friction on the nose gear) to the total weight borne by the main and nose gear tires. The airplane braking coefficient is dependent on runway, tire, and brake conditions, as well as the efficiency of the braking system's anti-skid function, but is independent of the use of spoilers and thrust reversers. The airplane braking coefficient is related to, but different from, runway mu readings and should not be directly compared.

The event airplane braking coefficient model was then used to calculate the stopping distance of the aircraft on the runway if spoilers and thrust reversers had been deployed upon touchdown per Southwest Airlines operational procedures. The landing distance results indicate the aircraft landing with spoilers per procedure and maximum thrust reversers would require 3,625 feet of ground roll (stopping 1,964 feet before the end of the runway), whereas landing with just spoilers per procedure (no thrust reversers at all) would require 4,691 feet of ground roll (stopping 898 feet before the end of the runway).

ORGANIZATIONAL AND MANAGEMENT INFORMATION

Southwest Airlines Co. was certificated as a 49 CFR Part 121 air carrier and is headquartered in Dallas, Texas. At the time of the incident, the company employed nearly 35,000 employees, operating more than 3,400 flights a day serving 72 cities in 37 states. As of March 27, 2011, Southwest Airlines reported 230 daily departures from MDW.

On September 26, 2010, the company entered into a merger agreement to acquire AirTran Holdings, Inc. At the time of the incident, the transaction had not yet been closed.

As of December 31, 2010, the company's fleet consisted of 548 Boeing 737 airplanes, including 171 -300s, 25 -500s, and 352 -700s.

The incident airplane was owned by Castle 2003-1A LLC and operated by Southwest Airlines Co. for common carrier passenger operations.

ADDITIONAL INFORMATION

Landing Distance Calculations and Factors

The Southwest Airlines FRM stated that the OPC is the primary source for takeoff, cruise, and landing data. Pilots input aircraft weight, systems information, and known environmental conditions (wind and runway conditions), and the OPC provides an output that indicates the approximate stopping margin on the runway of intended landing for the given inputs. The approximate stopping margin includes 1,500 feet for air distance from threshold to touchdown and an extra 15 percent distance factor. Stopping margin is the distance remaining after the aircraft comes to a complete stop. A positive stopping margin returned in the output would be acceptable for landing, and a negative margin (indicated by red highlight and bracketing) would not be acceptable for landing.

Following the wet/fair input by the flight 1919 crew, the OPC landing output indicated a stopping margin of 210 feet using maximum (auto) braking and maximum reverse thrust. The actual Southwest OPC calculated stopping distance for fair runway conditions is 3,586 feet after touchdown, which is consistent with the Boeing simulation study results for spoilers and thrust reversers deployed per procedures. Accounting for the 1,500-foot air distance, the aircraft was expected to stop 5,086 feet past the runway threshold, 973 feet before the end of the pavement.

Investigators also used the actual weather data at the time of touchdown to determine how the Southwest OPC landing distance would change. With winds of 220 degrees at 12 knots gusting to 16 knots (the OPC required wind direction inputs to be in multiples of 10, for example, 200, 210, 220) and the postincident weight of 124,520 pounds, the landing distance increased slightly due to the 30-degree change in wind direction. However, the aircraft was still predicted to stop 5,112 feet past the displaced threshold, or 3,612 feet after the assumed touchdown location using maximum (auto) braking.

Guidance contained in the Boeing and Southwest flight crew manuals identified factors affecting the landing distance. The main factors identified were touchdown point, speedbrake (spoiler) deployment, use of thrust reversers, and wheel braking. According to the Southwest Airlines FOM guidance, “speedbrake deployment is required to achieve the computed stopping margin. On initial landing roll, braking effectiveness is reduced by as much as 60 percent without speedbrake deployment.”

The Southwest Airlines FOM also stated that the pilot monitoring (PM) should ensure speedbrake and reverse thrust deployment and make appropriate callouts if either fails to deploy. Further, the manual noted that stopping margin computations are based on selecting reverse thrust within 2 seconds after touchdown and attaining the planned reverse thrust level within 8 seconds after touchdown. Any delay invalidates OPC stopping margin computations.

According to Southwest Airlines FOM guidance, both crewmembers were to verify deployment of the speedbrake lever on landing. The first officer, regardless of whether he was pilot flying (PF) or PM, was responsible for calling out any failure of the speedbrake lever to deploy by stating “Speedbrake.” The landing roll procedure included in the Boeing flight crew operating manual (FCOM) indicated that both pilots were to verify that the speedbrake lever was up and

that the PM was required to call “SPEED BRAKES UP” or, if the speedbrake lever was not up, call “SPEED BRAKES NOT UP.” The flight crew stated that the speedbrakes did not deploy during the initial landing roll and that they did not deploy them manually.

The Southwest FOM states that the PF is to initiate reverse thrust on landing while flying the nosewheel to the runway and that the PM is to verify thrust reverser activation and call out any failure to deploy by stating “reverser.” The Boeing FCOM includes guidance for the PF to apply thrust reversers on landing but does not specify a verbal crew callout. The Boeing flight crew training manual states that the PM should monitor engine operating limits and call out any thrust reverser failure or abnormality.

In February 2011, Southwest Airlines provided guidance to flight crews regarding the use of speedbrakes on landing in the form of a video presentation displayed in the flight crew rooms at each crew base. The company had also published guidance in 2008 on the use of thrust reversers and the significance of speedbrake use on landing to increase crew awareness of these issues.

Use of Automation

At the time of the incident, Southwest Airlines had recently transitioned the fleet and flight crews to the use of automation. Prior to this transition, the glass instrumentation on the flight deck included an analog presentation of flight instruments, autothrottle systems had been deactivated on the fleet, and they were not utilizing VNAV (vertical navigation) or RNAV.

The Southwest Airlines senior manager of NextGen and Airspace stated that the company had completed a four-step process to implement the transition beginning in late 2008. Training for the conduct of RNAV RNP approaches was completed during step 4 of the transition in the last half of 2010. The training consisted of an 8-hour ground school session and a 6-hour simulator training day, which included 4 hours in the simulator and 2 hours of briefing. Southwest Airlines began the use of RNP approaches during line operations on January 11, 2011.

During the transition period, Southwest Airlines flight operations conducted a study of the automation and RNP training program as part of a newly formed quality assurance program. The study included a randomly sampled group of line pilots to be evaluated via observation during simulator scenarios. In addition to the quality assurance program, ASAP and FDAP analyses, as well as weekly updates from subject matter experts, were used to monitor the effectiveness of the automation and RNP training and its implementation in line operations. Although the quality assurance reports projected a high rate of failure for pilots in the automation training program, the monitoring and reporting programs did not support that prediction. A separate Southwest Airlines safety and security analysis intended to identify any problem trends with the implementation of the automation program saw an initial increasing trend that reversed to pre automation levels.

Aviation Safety Reporting System (ASRS)

Database search requests were submitted to NASA's ASRS program to identify reports of 737 speedbrake-related incidents involving flight crew human performance issues during landing configuration or rollout, as well as RNP-related incidents. No reports relevant to the circumstances of this event were identified related to speedbrake arming. Of the seven RNP related reports identified in the search, three described confusion, automation management, and situational awareness issues while flying RNP procedures, and one described challenges associated with incompatibilities between ATC speed and altitude clearances and an RNP approach.

Previous Recommendations

Following the landing overrun accident involving American Airlines flight 1420 in Little Rock, Arkansas, on June 1, 1999, the NTSB issued Safety Recommendations A-01-49 and -50 to the FAA regarding the arming, verification, and deployment of spoilers on landing. The recommendations were as follows:

For all 14 Code of Federal Regulations Part 121 and 135 operators of airplanes equipped with automatic spoiler systems, require dual crewmember confirmation before landing that the spoilers have been armed, and verify that these operators include this procedure in their flight manuals, checklists, and training programs. (A-01-49)

For all 14 Code of Federal Regulations Part 121 and 135 operators, require a callout if the spoilers do not automatically or manually deploy during landing and a callout when the spoilers have deployed, and verify that these operators include these procedures in their flight manuals, checklists, and training programs. The procedures should clearly identify which pilot is responsible for making these callouts and which pilot is responsible for deploying the spoilers if they do not automatically or manually deploy. (A-01-50)

In response to the recommendations, the FAA amended Advisory Circular (AC) 120-71, "Standard Operating Procedures for Flight Deck Crewmembers," which included guidance to operators on the arming of spoiler systems and the flight crew callouts for spoiler deployment on landing. AC 120-71 included the following items in Appendix 1, Standard Operating Procedures Template:

Auto spoiler and auto brake systems armed and confirmed armed by both pilots, in accordance with manufacturer's recommended procedures (or equivalent approved company procedures)

And;

Actions and callouts during rollout (see example, Appendix 18)
"No Spoilers" callout

Appendix 18, Landing Rollout – Actions and Callouts, included an example that indicated the PM should make a “no spoilers” callout if appropriate.

Following the December 8, 2005, landing overrun accident involving Southwest Airlines flight 1248, off the departure end of runway 31C at MDW (the opposite direction on the same runway as this incident), the NTSB issued Safety Recommendation A-07-60 regarding the monitoring of thrust reverser status immediately after touchdown, asking the FAA to:

Require all 14 Code of Federal Regulations Part 121 and 135 operators of thrust reverser-equipped airplanes to incorporate a procedure requiring the non-flying (monitoring) pilot to check and confirm the thrust reverser status immediately after touchdown on all landings.

In response to the recommendation, the FAA stated that AC 120-71A, “Standard Operating Procedures for Flight Deck Crewmembers,” explicitly recommends a procedure for the PM to monitor thrust reverser deployment and advise the PF of thrust reverser status.

Although this guidance has been included in AC 120-71A since February 2003, the NTSB noted in response to the FAA that investigations of runway overrun incidents and accidents have found that not all air carriers have implemented procedures that are consistent with this guidance.

Information

Certificate:	**Age:**
Airplane Rating(s):	**Seat Occupied:**
Other Aircraft Rating(s):	**Restraint Used:**
Instrument Rating(s):	**Second Pilot Present:**
Instructor Rating(s):	**Toxicology Performed:**
Medical Certification:	**Last FAA Medical Exam:**
Occupational Pilot:	**Last Flight Review or Equivalent:**
Flight Time:	

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	**Registration:**	N799SW
Model/Series:	737-7Q8	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	28209
Landing Gear Type:	Retractable - Tricycle	**Seats:**	149
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	CFM
ELT:		**Engine Model/Series:**	CFM56
Registered Owner:	CASTLE 2003-1A LLC	**Rated Power:**	
Operator:	SOUTHWEST AIRLINES CO	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:		**Operator Designator Code:**	SWAA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KMDW,620 ft msl	**Distance from Accident Site:**	1 Nautical Miles
Observation Time:	13:28 Local	**Direction from Accident Site:**	310°
Lowest Cloud Condition:	Scattered / 900 ft AGL	**Visibility**	2 miles
Lowest Ceiling:	Broken / 1500 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	10 knots / 17 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	220°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.4 inches Hg	**Temperature/Dew Point:**	16°C / 14°C
Precipitation and Obscuration:	N/A - None - Mist		
Departure Point:	Denver, CO (KDEN)	**Type of Flight Plan Filed:**	IFR
Destination:	Chicago, IL (KMDW)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	

Airport Information

Airport:	Chicago Midway KMDW	**Runway Surface Type:**	Asphalt;Concrete
Airport Elevation:	620 ft msl	**Runway Surface Condition:**	Standing water;Wet
Runway Used:	13C	**IFR Approach:**	ILS
Runway Length/Width:	6522 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	134 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	
Total Injuries:	139 None	**Latitude, Longitude:**	41.89046,-87.620109(est)

Administrative Information

Investigator In Charge (IIC):	English, William
Additional Participating Persons:	
Original Publish Date:	June 11, 2012
Last Revision Date:	
Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=78976