NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

July 31, 20011

Group Chairman's Factual Report

OPERATIONAL FACTORS / HUMAN PEFORMANCE

DCA11IA047

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A. INCIDENT

Operator:	Southwest Airlines, Inc.
Location:	Chicago, IL
Date:	April 26, 2011
Time:	1533 central daylight time[1]
Airplane:	Boeing 737-700, Registration Number: N799SW, Serial #: 28209

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C. SUMMARY

On April 26, 2011, about 1333 central daylight time (CDT), a Boeing 737-700, registration N799SW, operated by Southwest Airlines as flight 1919, exited the left side of runway 13C upon landing at the Chicago Midway International Airport, Chicago, Illinois (MDW). The flight was a regularly scheduled flight from Denver International Airport, Denver, Colorado (DEN). Initial data indicates that weather was moderate rain with southerly winds at the time of the excursion. The aircraft had minor damage to landing gear and the right engine due to contact with a taxiway light. There were no reported injuries among the 134 passengers and 5 crew. Passengers exited via airstairs.

[1] All times are central daylight time (CDT) based on a 24-hour clock, unless otherwise noted. Actual time of incident is approximate.

D. DETAILS OF THE INVESTIGATION

The Operations Group learned of the incident on April 26, 2011 and began to form at that time. The group included members of Operational Factors and Human Performance from the NTSB and members from FAA, Boeing, Southwest Airlines, and the Southwest Airlines Pilots' Association.

From the company the group collected flight crew statements and flight documentation including the flight release, weight and balance, OPC (Onboard Performance Computer) data, ACARS (Aircraft Communications Addressing and Recording System) messaging, and requested information regarding flight crew training records, duty time and rest records, flight crew manuals, and training materials and courseware related to crew resource management, the use of automation, and the conduct of RNP (Required Navigation Performance) approaches. From Boeing the group collected the manufacturer's flight manuals and documents. From the FAA the group reviewed the flight crews' certification records and medical history and information from the PTRS (Program Tracking and Reporting System).

On May 5, 2011, the group conducted interviews[2], via telephone from NTSB headquarters, with the incident captain and incident first officer.

On June 14, 2011, the group interviewed, via telephone from NTSB headquarters, the Southwest Airlines senior manager of NextGen and airspace, and the manager of procedures.

On June 15, 2011, the group conducted an interview, via telephone from NTSB headquarters, with the Southwest Airlines CRM manager.

E. FACTUAL INFORMATION

1.0 History of Flight

The incident flight crew departed DEN about 1105 mountain daylight time (1205 CDT) for MDW on the third flight of their trip.[3] The captain was the pilot flying (PF) and the first officer was the pilot monitoring (PM). During their initial descent, the flight crew was advised by ATC that MDW was only accepting flights capable of conducting an RNAV (RNP) approach. The crew proceeded to brief and set up for the RNAV (GPS) Z approach to runway 13C, rather than the RNAV (RNP) Y approach, and calculated the landing performance using the OPC. Due to weather in the Chicago area, the flight crew held at the SMARS intersection for approximately 30 minutes.

[2] See Attachment 1 – Interview Summaries.

[3] According to the captain and first officer the previous flights that day, the flight prior to top of descent, and the performance of the other pilot were unremarkable. The captain reported that the first officer may have purchased breakfast at MDW and ate it during the flight to DEN.

After holding, the flight crew was given a radar vector to Joliet and instructed to join the final approach for the RNAV (RNP) Y runway 13C[4], and maintain a speed of 170 knots. At this time, the flight crew briefed and set up the FMC (Flight Management Computer) for the RNAV (RNP) Y approach. During the approach, the flight crew heard a braking action report of "fair" for the runway of intended landing. As a result, the crew re-calculated the landing performance using the OPC and confirmed a positive landing distance margin under "wet-fair" conditions.

According to the flight crew, they were close to the speed limits for flap deployment but were able to configure the airplane for landing and were stabilized on approach by 1,000 feet above touchdown zone elevation. The crew said that they were aware of a cell with rain showers that had just crossed over the field, and attempted to determine its direction of movement.

According to the captain, the airplane touched down within the first 1,000 feet of the runway. The captain de-activated the autobrake system immediately after landing by using the manual brakes and after a delay deployed the thrust reversers during the ground roll.[5] The captain stated that he deployed the thrust reversers after he heard the first officer make a thrust reverser callout, but he could not recall how long after touchdown that occurred. Information obtained from the Flight Data Recorder (FDR) indicated that the speedbrakes were not armed, and did not deploy, until after a thrust lever was positioned for reverse thrust.

The captain attempted to turn the airplane onto the last taxiway on the left side of the runway but stated that the airplane was still moving too fast to make the turn. The airplane exited the left side of the runway end and came to rest in the grass and mud adjacent to the EMAS[6].

2.0 Flight Crew Information[7]

The incident flight crew consisted of a captain, a first officer, and 3 cabin crew members. The captain and first officer had flown together about two weeks prior to the incident. The incident flight occurred on the third leg of the first day of a three day trip. The trip started at Baltimore/Washington International Airport (BWI) with a scheduled report time of 0515. The crew flew from BWI to MDW on the first leg and from MDW to DEN on the second leg.

2.1 The Captain

The captain was 50 years old and was hired by Southwest Airlines in January of 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 BWI.

He began his career at the age of 19 and earned his commercial and instrument pilot certificates before joining the USAF as enlisted personnel. After about 5 years in the USAF he was accepted

[4] See Attachment 7 – Approach Chart.
[5] See the Flight Data Recorder Group Chairman's Factual Report.
[6] EMAS – Engineered Materials Arresting System.
[7] Clock times in this section reflect eastern daylight time (edt).

into USAF pilot training. He graduated from USAF pilot training in 1986, was an instructor pilot for about 4 years, and then flew C-130 airplanes before separating from the USAF in 1992.

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.

2.1.1 The Captain's Pilot Certification Record

FAA records of the Captain indicated that:

Private Pilot - Airplane Single Engine Land certificate was issued on April 4, 1980 on the basis of a Mexico Pilot Certificate.[8]
Commercial Pilot – Airplane Single Engine Land – Instrument Airplane certificate was issued on August 29, 1980.
Commercial Pilot – Airplane Single and Multi Engine Land – Instrument Airplane certificate was issued on September 17, 1980. An L-382 type rating was added on February 20, 1992.
Airline Transport Pilot – Airplane Multiengine Land – Commercial Privileges – Airplane Single Engine Land certificate was issued on May 21, 1992 with a B737 type rating under Airline Transport Pilot privileges and an L-382 type rating under Commercial privileges.

There were no testing or checking failures in the FAA records.

2.1.2 The Captain's Pilot Certificates and Ratings Held at Time of the Accident

AIRLINE TRANSPORT PILOT (issued April 7, 2009)
AIRPLANE MULTIENGINE LAND
B737
COMMERCIAL PRIVILEGES
AIRPLANE SINGLE ENGINE LAND
L-382

MEDICAL CERTIFICATE FIRST CLASS (issued February 17, 2011)
Limitations: None

2.1.3 The Captain's Training and Proficiency Checks Completed

Initial Type Rating Boeing 737: May 21, 1992

[8] In accordance with FAA Order 8900.2, Title 14 Code of Federal Aviation Regulations (CFR) Part 61 allows that a person may be issued a U.S. pilot certificate with private pilot privileges based on a foreign-pilot license that is at least equivalent to the U.S. private pilot certificate; provided that the foreign-pilot license was issued by a foreign civil aviation authority that was a member state to the International Civil Aviation Organization.

Last recurrent simulator training: May 25, 2010
Last recurrent ground training: November 27, 2010
Last Line Check in Boeing 737: August 30, 2010
Last Proficiency Check: November 28, 2010

The company reported that the captain had no unsatisfactory proficiency checks or line checks.

2.1.4 The Captain's Flight Times

The captain's flight times, based on Southwest Airlines employment records:

Total pilot flying time	10,800 hours
Total Pilot-In-Command (PIC) time	8,000 hours
Total B737 flying time	9,000 hours
Total B737 PIC time	7,000 hours
Total flying time last 24 hours	6 hours
Total flying time last 7 days	17 hours
Total flying time last 30 days	53 hours
Total flying time last 90 days	157 hours
Total flying time last 12 months	568 hours

2.1.5 The Captain's 72-Hour History

During the month preceding the event, the captain flew 4 trips: From March 30 through April 1, he flew a 3-day trip accumulating 27 hours 22 minutes duty time (20 hours 1 minute block time); From April 5-7, after about 61 hours off-duty, he flew a 3-day trip accumulating 29 hours 57 minutes duty time (17 hours 50 minutes block time); From April 12-14, after about 57 hours off-duty, he flew a 3-day trip accumulating 27 hours 32 minutes duty time (18 hours 21 minutes block time); From April 20-22, after about 60 hours off-duty, he flew a 3-day trip accumulating 23 hours 27 minutes duty time (17 hours 22 minutes block time).

The captain described his activities in the days before the incident. On April 23 he awoke about 0800 and reported routine activities around home before going to bed about 2300. On April 24 he awoke about 0800 and reported obtaining about 7 to 8 hours of good quality sleep. He hosted guests at the house and went to bed about 2230-2300. On April 25 he awoke about 0700-0730 and reported obtaining about 7 to 7½ hours of good quality sleep. He reported routine activities around the house before going to bed about 2100-2130. On April 26 he awoke about 0315 and reported obtaining about 5 ½ to 6 hours of good quality sleep. During his 1 hour and 10 minute drive to the airport he ate some fruit and a protein shake. He arrived BWI before his scheduled check-in time.

2.1.6 The Captain's Personal Background

The captain lived at home with his wife in Easton, MD. He stated that nothing affected his quality of sleep in the days before the incident and described his activities during the period as routine. He normally went to bed about 2300 and woke around 0700, and needed about 6-7 hours of sleep to feel rested. He reported no sleep disorders or any factors that would affect his quality of sleep other than waking to use the toilet (estimated once every night). He described his vision, hearing, and overall health as good and stated that he had achieved a 20-25 pound weight loss in the last year. He took a daily vitamin supplement and reported taking no medications that may have affected his performance in the days before the incident. He said he occasionally consumed alcohol (last consumed during a brunch on April 24). He consumed about 1-2 Diet Pepsi's per day and smoked about 1 pack of cigarettes every 3 or 4 days. His finances and personal life were stable in the recent months. When asked to reflect on his activities and situation in the days before the incident he stated that there was nothing he could think of that would have adversely affected his performance.

2.2 The First Officer

The first officer was 50 years old and was hired by Southwest Airlines in July 2002. He was based at BWI.

He began his career receiving instruction from his father, who was a retired USAF officer and flight instructor, and then earning his private pilot certificate. In 1985 he pursued aviation full-time and in 1986 began flying pipeline patrol, earned his CFI, and commercial instrument rating. He then spent about a year flying single engine piston aircraft in Africa for a nonprofit organization; and about 4½ years flying light twins and turboprops for a company in the Chicago area; and then did contract work delivering BE-1900 and B350 airplanes overseas. From 1997 to September 2001 he flew for Midway Airlines flying a regional jet (CRJ).

He reported about 17,000 hours total time including an estimated 7,000 hours of B737 SIC time.

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

2.2.1 The F/O's Pilot Certification Record

FAA records of the F/O indicated that:

Private Pilot - Airplane Single Engine Land certificate was issued on April 3, 1983.
Commercial Pilot – Airplane Single Engine Land certificate was issued on September 18, 1986 with the restriction, "carrying passengers in airplanes for hire is prohibited at night and on cross-country flights of more than 50 nautical miles."
Commercial Pilot – Airplane Single Engine Land – Instrument Airplane was issued on June 5, 1987.
Flight Instructor – Airplane Single Engine certificate was originally issued on July 4, 1987.

Commercial Pilot – Airplane Single and Multi Engine Land – Instrument Airplane certificate was issued on November 28, 1987.

Airline Transport Pilot – Airplane Multiengine Land – Commercial Privileges – Airplane Single Engine Land certificate was issued on July 20, 1988. A BE-1900, second in command required, type rating was added on January 31, 1993. A BE-300 type rating was added on October 11, 1986. A CL-65, circling approach in VMC only, type rating was added on October 21, 1999; and a B737, circling approach in VMC only, type rating was added on July 27, 2001.

2.2.2 The F/O's Pilot Certificates and Ratings Held at Time of the Accident

AIRLINE TRANSPORT PILOT (issued November 10, 2008)
AIRPLANE MULTIENGINE LAND
BE-300, BE-1900, CL-65, B737
COMMERCIAL PRIVILEGES
AIRPLANE SINGLE ENGINE LAND
LIMITATIONS:
BE-1900 SECOND IN COMMAND REQUIRED
CL-65 and B737 CIRC. APCH. – VMC ONLY

MEDICAL CERTIFICATE FIRST CLASS (issued July 12, 2010)
Limitations: Must wear corrective lenses

2.2.3 The F/O's Training and Proficiency Checks Completed

Initial Type Rating B737: July 27, 2001
Last recurrent simulator training: June 3, 2010
Last recurrent ground training: June 2, 2010
Last Proficiency check on B737: June 23, 2010

The first officer 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 Airline Transport Pilot (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.

2.2.4 The F/O's Flight Times

The accident F/O's flight times, based on Southwest Airlines employment records:

Total pilot flying time	17,000 hours
Total PIC time	7,500 hours

Total SIC time	9,500 hours
Total flying time in B737	7,000 hours
Total B737 second-in-command (SIC) time	7,000 hours
Total flying time last 24 hours	6 hours
Total flying time last 7 days	11 hours
Total flying time last 30 days	82 hours
Total flying time last 90 days	210 hours
Total flying time last 12 months	795 hours

2.2.5 The F/O's 72-Hour History

During the month preceding the event, the first officer flew 7 trips: From March 28-30, he flew a 3-day trip accumulating 27 hours 4 minutes duty time (19 hrs 36 minutes block time); From March 31 through April 1, after about 25 hours off-duty, he flew a 2-day trip accumulating 13 hours 7 minutes duty time (4 hours 37 minutes block time); From April 5-7, after about 60 hours off-duty, he flew a 3-day trip accumulating 31 hours 35 minutes duty time (20 hours 9 minutes block time); On April 9, after about 10 hours off-duty, he flew a 1-day trip accumulating 10 hours 25 minutes duty time (5 hours 10 minutes block time); From April 12-13, after about 31 hours off-duty, he flew a 2-day trip accumulating 15 hours 24 minutes duty time (10 hours 31 minutes block time); From April 15-17, after about 32 hours off-duty, he flew a 2-day[9] trip accumulating 21 hours 26 minutes duty time (10 hours 34 minutes block time). From April 20-21, after about 32 hours off duty, he flew a 2-day trip accumulating 21 hours 8 minutes duty time (11 hours 57 minutes block time).

The first officer had difficulty recalling his specific activities in the days before the incident and information in this section is based on his rough estimates. On April 22 he went to sleep about 2230-2300. On April 23 he awoke about 0800 and reported obtaining about 8 to 8 ½ hours of sleep. He reported doing routine activities around home before and going with his family to a friend's house for dinner that evening. He went to bed around 2300-2330. On April 24 he awoke about 0700 and reported obtaining about 8 hours of sleep. He reported routine activities around home that day before going to sleep about 2200-2300. On April 25 he awoke about 0700-0730 and reported obtaining about 8 hours of sleep. He reported routine activities around home that day before departing RDU around 1900 for BWI. About 2300 he went to sleep at his crash pad in the BWI area. On April 26 he awoke about 0405 and reported getting about 5 hours of sleep which he described as "fine." He departed the crash pad about 0430 for his 10 minute commute to the airport for his 0515 report time.

2.2.6 The FO's Personal Background

The first officer lived in the Raleigh Durham area with his wife, two sons, and a daughter (children ages 12-17). He characterized his activities in the days before the event as not unusual and stated he slept well and had no recall of waking up at night or anything out of the ordinary. He said he normally woke up about 0700 and went to sleep about 2300 and had no sleep

[9] Trip ended at 0056 on April 17.

disorders or conditions which affected his ability to obtain sleep. He was unable to provide a specific amount of sleep that he needed to feel wide awake and alert throughout the day but offered that 7 hours of sleep is fine for him but he was able to function OK with less. He stated his vision was corrected for distance and his hearing was good, and he was in good health on the day of the event and in the preceding 3 days. He reported taking no medications, prescription or non prescription that could have affected his performance. He was a nonsmoker who drank alcohol occasionally, most recently on Saturday evening. The first officer described his personal situation as somewhat stressful as they were dealing with a health problem involving his older son and had lost their oldest son in August a couple years ago. However he stated that his personal situation did not affect his performance on the day of the incident and nothing in the days before the incident affected his performance during the approach and landing other than the timing of the operational distractions that occurred during the approach and landing.

2.3 Medical and Pathological Information

2.3.1 The Flight Crew's Post-Accident Toxicological Testing

On April 26, 2011, the captain and F/O 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[10].

3.0 Weight and Balance

The weight and balance information was obtained from the Southwest Airlines Loading Schedule and from ACARS messaging (unless otherwise noted):

Basic Operating Weight	85,363 lbs
Passenger Weight	26,100 lbs
Baggage & Cargo	3,802 lbs
Zero Fuel Weight	115,265 lbs
Fuel	21,396 lbs
Takeoff Weight	136,661 lbs
Maximum Takeoff Weight Allowed[11]	137,600 lbs
Landing Weight	124,520 lbs
Maximum Landing Weight Allowed	128,000 lbs

[10] Southwest Airlines provided results to the Safety Board indicating that both pilots tested negative for the following drugs: marijuana, cocaine, amphetamines, opiates, and PCP. The results also indicated that the captain and first officer submitted to breathalyzer tests at 1744 and 1759, respectively, on April 26, 2011, and the results were negative.

[11] The maximum structural takeoff weight limit was 154,500 pounds. For this flight, the takeoff weight was limited by landing weight and the expected enroute fuel burn of 9,600 pounds.

According to operator and manufacturer guidance, the airplane was within the approved center of gravity and weight limits for landing on runway 13C at MDW.

4.0 Aerodrome Information

Airport information was obtained from the Federal Aviation Administration's Aeronautical Navigation Products Office (AeroNav) Terminal Procedures Publication (TPP) and Airport Facility Directory (AFD). At the time of the incident, MDW field elevation was reported as 620 feet above mean sea level and was located approximately 9 miles southwest of Chicago, IL. The airport had 10 hard surface runways; the longest was runway 13C. AFD data indicated runway 13C was grooved concrete, was 6,522 feet long and 150 feet wide with a displaced threshold of 463 feet leaving 6,059 feet landing distance available (LDA)[12]. AFD data indicated there was a road at each end of the runway and an Engineered Materials Arresting System (EMAS) installed.

Runway 13C had precision runway markings, high intensity runway lights (HIRL), a lead in light system (LDIN), and a 4 light precision approach path indicator (PAPI) located on the right side of the runway displaying a 3 degree glide path.

5.0 Meteorological Information

The automatic terminal information service (ATIS) at MDW airport was broadcasting the following weather report prior to the incident:

> *Midway airport information Oscar, 1751 zulu, wind 190 at 16, gusts 23, visibility 6, light rain, mist, 800 scattered, ceiling 1,400 broken, 2,200 overcast, temperature 16, dewpoint 14, altimeter 29.40, ILS runway 13 center approach in use. Landing and departing runways 13, also departing runway 22 left. Notices to airmen, taxiway alpha closed between runway 31 center and runway 31 left, aircraft should operate mode C on all taxiways and runways. Non pre-departure clearance aircraft contact clearance delivery on 121.85, vfr departures indicate type aircraft, field location and requested heading. Midway approach control on frequency on 118.7. Read back all runway hold short instructions and altitude assignments. Advise on initial contact you have information Oscar*

The flight crew received the ATIS information onboard the airplane via ACARS[13] messaging, and had on board, weather reports and forecasts that were part of the Flight Release[14].

[12] The Airport Facility Directory Legend defined LDA as "The length of runway which is declared available and suitable for the ground run of an aeroplane landing."
[13] ACARS – Aircraft Communications Addressing and Reporting System.
[14] See Attachment 2 – Flight Release.

6.0 Company Overview

Southwest Airlines Co. was certificated as a Federal Aviation Administration (FAR) part 121 air carrier and was headquartered in Dallas, TX. According to information provided on the company's website[15], Southwest Airlines began service on June 18, 1971 with three B737 airplanes serving three cities in 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 Midway Airport.

On September 26, 2010, the company entered into a merger agreement for the company's acquisition of 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 B737 airplanes, including 171 B737-300, 25 B737-500, and 352 B737-700[16].

The incident airplane was owned by Castle 2003-1A LLC, and operated by Southwest Airlines Co. for FAR Part 121 passenger carrying operations.

7.0 Landing Data Calculations

Southwest Airlines flight crews used the Onboard Performance Computer (OPC) to calculate landing data.

The Southwest Airlines Flight Reference Manual revision 10-4, dated July 15, 2010, page 8.1.1stated in part:

> *The Onboard Performance Computer is the primary source for takeoff, cruise, and landing data.*

The OPC software included a database of airport and runway information which was updated every 28 days[17].

Pilots input aircraft weight, systems information, and known environmental conditions (winds and runway conditions), and the OPC provided an output that indicated the approximate stopping margin on the runway of intended landing for the given inputs. The Approximate Stopping Margin was defined in the Southwest Airlines Flight Reference Manual as:

> *Approximate Stop Margin—based on minimum, medium, and maximum braking and corresponds to three different auto brake settings (2, 3, and MAX). Each stop margin calculation includes 1500 ft air distance from threshold to touchdown and an extra 15*

[15] Information received from website of Southwest Airlines, Co. < http://www.southwest.com/html/about-southwest/history/fact-sheet.html> (accessed June 21, 2011).
[16] Southwest Airlines Co. Annual Report for the fiscal year ended December 31, 2010, Form 10-K, filed February 8, 2011.
[17] Southwest Airlines Flight Reference Manual, page 8.1.1, revision 10-04, dated July 15, 2010.

percent distance factor. Stop margin is the distance remaining after the aircraft comes to a complete stop, measured from the nose gear to the end of the available runway. If the estimated landing distance is longer than the available runway length, the approximate stop margin is negative, highlighted, and bracketed "[ ]".[18]

Interviews with company personnel indicated that any positive stopping margin returned in the output was acceptable for landing.

The flight crew input weather data obtained from ATIS and initially calculated landing data based on a runway condition of wet with good braking. The initial landing data output indicated a stopping margin of 720 feet using maximum braking and thrust reversers in detent 2. After obtaining a braking action report from the pilot of an airplane which landed an airplane approximately 6 minutes prior to their arrival, the flight crew re-calculated the landing data based on a runway condition of wet with fair braking.

The OPC Landing output indicated a stopping margin of 210 feet using maximum braking and maximum reverse thrust[19].

7.1 Factors Affecting Landing Distance

Guidance contained in the Boeing and Southwest flight crew manuals identified factors affecting the landing distance. The main factors identified were Touchdown point, speed brake deployment, use of thrust reversers, and wheel braking.

7.1.1 Touchdown Point

Guidance in the Southwest Airlines Flight Operations Manual (FOM) stated that the OPC approximate stopping margin information was based on the assumption that the airplane touched down no later than 1,500 feet from the useable end of the runway, and that if touchdown occurred beyond that point, the ability for the airplane to stop on the remaining runway "may be compromised"[20].

7.1.2 Speed Brakes

According to FOM guidance, speed brake deployment was required in order to achieve the computed stopping margin. The Southwest Airlines FOM, Chapter 3, Section 22, page 3.22.2 stated in part:

> ***Warning:*** *Speed brake deployment is required to achieve the computed stopping margin. On initial landing roll, braking effectiveness is reduced by as much as 60 percent without speed brake deployment. Speed brakes increase aerodynamic drag and the effective weight on the landing gear.*

[18] Southwest Airlines Flight Reference Manual, page 8.4.36, revision 11-01, dated March 31, 2011.
[19] See Attachment 3 – OPC Landing Output.
[20] Southwest Airlines Flight Operations Manual, Chapter 3, Section 22, page 3.22.1, revision 1-08, dated April 7, 2008.

Similar guidance was contained in the Boeing 737 Flight Crew Training Manual (FCTM).

In addition, the FOM Chapter 3, Section 23, page 3.23.6 discussed landings with FAIR or POOR braking action advisories. This section contained a warning that stated:

> ***Warning:*** *Any delay in the application of reverse thrust, speed brakes, or wheel brakes will invalidate the OPC stopping margin predictions and may result in the inability to stop in the remaining distance.*

The section also stated that the pilot monitoring should:

> *(PM) Ensure speed brake and reverse thrust deployment. Make appropriate callouts if either fails to deploy.*

7.1.3 Thrust Reversers

Guidance on the use of engine thrust reversers on landing was included in company manuals. The Southwest Airlines FOM Chapter 3, Section 22, page 3.22.2 stated in part:

> *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 will invalidate OPC stopping margin computations.*

The Boeing FCTM included the following note regarding the use of reverse thrust and speed brakes on landing:

> ***Note:*** *Reverse thrust and speedbrake drag are most effective during the high speed portion of the landing. Deploy the speedbrake lever and activate reverse thrust with as little time delay as possible.*[21]

7.1.4 Braking

Southwest Airlines guidance provided for the use of either the auto brake system or manual braking.

The following note was included in the Boeing FCTM:

> ***Note:*** *Speedbrakes fully deployed, in conjunction with maximum reverse thrust and maximum manual antiskid braking provides the minimum stopping distance.*[22]

[21] Boeing 737 Flight Crew Training Manual, chapter 6 page 6.40, dated June 30, 2010.
[22] Boeing 737 Flight Crew Training Manual, chapter 6 page 6.40, dated June 30, 2010.

The Boeing FCTM also included a graphic illustrating the "increase in typical landing distance due to improper landing techniques"[23].

8.0 Flight Crew Procedures

Southwest Airlines flight crew procedures were based on Boeing guidance and modified for operational need. Airplane systems information was contained in the Flight Reference Manual (FRM) and flight crew procedural guidance was contained in the Flight Operations Manual (FOM) and the Quick Reference Handbook (QRH). Additional guidance was available to crews in the Flight Operations Training Manual (FOTM).

8.1 Speed Brake

Guidance in the FOM indicated that the speedbrake was to be armed by the captain during approach while the flight crew was configuring for landing. The FOM, Chapter 3, page 3.13.8, stated in part:

> *(CA) Ensure that the speedbrake is out of the detent and the SPEED BRAKE ARMED light is illuminated.*

Confirmation of the speed brake arming was to be accomplished by use of the Before Landing Checklist which was contained in the FOM, Chapter 3, page 3.13.9, as follows:

> *The PM reads and verifies, and the PF verifies and responds.*

Before Landing	
Speedbrake	*Armed, Green Light*
Landing Gear	*Down, 3 Green*
Flaps	*____, Green Light*

A laminated copy of the FAA approved checklist was carried on the flight deck.

Guidance contained in the Boeing Flight Crew Operations Manual (FCOM), page NP.21.63 indicated that the speed brake was to be armed by the pilot flying (PF). The Boeing QRH included guidance for both pilots to confirm arming of the speedbrake while performing the Landing checklist[24].

The flight crew did not recall completing the Before Landing Checklist.

[23] See Attachment 4 – Landing Distance Increase.
[24] Boeing Quick Reference Handbook, Chapter CI, Section 1, page CI.1.1, dated May 15, 2008.

8.1.1 Speed Brake Deployment on Landing

When armed, the speed brake would automatically deploy on landing if[25]:

- The radio altimeter was less than 10 feet
- The landing gear strut compressed on touchdown
- Both thrust levers were retarded to IDLE, and
- Main landing gear wheels spin up (more than 60 knots)

According to FOM guidance, both crew members were to verify deployment of the speed brake on landing. The FOM Chapter 3, Section 22, pages 3.22.1 and 3.22.2 stated in part:

> *At touchdown, verify that the automatic speedbrakes deploy.*
>
> - *(CA) If the automatic speedbrakes do not deploy, deploy them manually.*
> - *(FO) verify speed brake deployment. Call out any failure to deploy by stating, "Speed brake."*

The Landing Roll Procedure included in the Boeing FCOM indicated that both pilots were to verify that the speed brake lever was up and that the pilot monitoring (PM) was required to call "SPEED BRAKES UP" or, if the speed brake lever was not up, call "SPEED BRAKES NOT UP."[26]

The flight crew stated that the speedbrakes did not deploy during the initial landing roll and that they did not deploy them manually.

According to the systems description in the Boeing FCOM, if the speed brake lever was in the down position (not armed) during landing the auto speed brake would deploy when[27]:

- Main landing gear wheels spin up
- Both thrust levers are retard to IDLE, and
- Reverse thrust levers are positioned for reverse thrust

According to information obtained from the FDR, the speedbrakes automatically deployed during the landing rollout after a thrust lever was positioned for reverse thrust.[28]

[25] Boeing Flight Crew Operations Manual, Chapter 9, Section 20, page 9.20.16 dated September 23, 2010.
[26] Boeing Flight Crew Operations Manual, Normal Procedures, Section 21, page NP.21.67, dated March 18, 2011.
[27] Boeing Flight Crew Operations Manual, Chapter 9, Section 20, page 9.20.17 dated September 23, 2010.
[28] Refer to Flight Data Recorder Group Chairman's Factual Report.

8.2 Thrust Reversers

The OPC landing data indicated that maximum reverse thrust was to be used for this landing. Normal procedures contained in the FOM chapter 3, Section 22, page 3.22.2 specified the following duties for the PF and PM regarding thrust reverser use on landing:

> ***(PF) Initiate Reverse Thrust***
>
> *While flying the nose wheel to the runway, raise the reverse thrust levers to the reverse idle interlocks. After the interlocks release, continue to raise the levers to detent 2…*
>
> ***(PM) Verify thrust reverser actuation. Call out any failure to deploy by stating, "Reverser."***

The captain stated in an interview that the FO had called out "thrust reversers" during the landing roll, and the captain deployed them at that time.

The Landing Roll Procedure in the Boeing FCOM includes guidance for the PF to apply thrust reversers but does not specify a verbal crew callout.

8.3 Autobrakes

The OPC landing data indicated that maximum braking was to be used for this landing. Normal procedure was to use the auto brake system and for the PF to transition to manual braking at an appropriate speed. The FOM, Chapter 3, Section 22, page 3.22.3 stated in part:

> *The intent of using the auto brake system for landing is to let the system automatically brake the aircraft to an appropriate speed, not to override the system shortly after touchdown.*
>
> *Auto brakes relieve the PF's workload by automatically initiating wheel braking at touchdown and maintaining an appropriate deceleration rate throughout the landing roll. This allows the PF to concentrate on speed brake deployment, reverse thrust application, directional control, and overall stopping performance.*

The captain stated in an interview that after touchdown he did not feel the normal deceleration that he was accustomed to so he "instinctively applied maximum brakes."[29] The FOM, Chapter 3, section 22, page 3.22.4 includes the following note:

> *Note: Anytime the ability to stop on the remaining runway becomes a concern, maximum deceleration may be achieved by immediately applying maximum manual braking and maximum reverse thrust.*

[29] See Attachment 1 – Interview Summaries (page 13).

The captain stated that the first officer called "auto brake disarmed" in accordance with FOM guidance for the PM during the landing roll.

The Landing Roll Procedure in the Boeing FCOM provided guidance for both crew members to "Verify correct autobrake operation"[30] but no crew call out was defined.

9.0 Use of Automation

At the time of the incident, Southwest Airlines policy on the use of automation was included in the FOM Chapter 3, Section 1, page 3.1.13 which stated, in part:

> *The Pilot Flying (PF) will choose the highest level of automation, unless otherwise required by procedure, to meet these ordered priorities:*
>
> - *Enhance safety and situational awareness*
> - *Support passenger service through increased operational capability*
> - *Maximize efficiency*

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, auto throttle systems had been deactivated on the fleet, and they were not utilizing VNAV[31] or RNAV[32].

The senior manager of NextGen and airspace stated[33] that the company had completed a 4 step process to implement the transition.

The first step included computer based training in November – December 2008 and in January of 2009 they began to use autothrottles and VNAV systems above 10,000 feet on the 737-700 fleet. The next step in the process included computer based training to familiarize flight crews with the use of PFD's[34], GPS[35] approaches, and RNAV fundamentals.

Step 3 of the transition was conducted between September 2009 and March 2010, and included one day of ground school and a simulator session which covered PFD's, GPS, and VNAV approaches. The final step in the transition, step 4, was conducted between May and November of 2010 and focused on the conduct of RNP approaches and engine out standard instrument departures.

Southwest Airlines began the use of RNP approaches during line flying operations on January 11, 2011.

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[30] Boeing Flight Crew Operations Manual, Normal Procedures, Section 21, page NP.21.67, dated March 18, 2011.
[31] VNAV – vertical navigation.
[32] RNAV – area navigation.
[33] See Attachment 1 – Interview Summaries (page 20).
[34] PFD – Primary Flight Display.
[35] GPS – Global Positioning System is a satellite based navigation system.

9.1 Autopilot and Autothrottles During Approach

The Southwest Airlines FOM Chapter 2, Limitations, contained guidance regarding the use of autothrottles and autopilot during approach. The FOM Chapter 2, Section 3, page 2.3.4 stated:

> *Minimum altitude for autothrottle disengagement during approach is 50 ft below DA/DDA, but no less than 50 ft AGL.*
>
> *During cruise, descent, or approach, autothrottle use is allowed only when the autopilot is engaged in the command (CMD) mode.*

The FOM Chapter 2, Section 3, page 2.3.3 included the following:

> *Flight director or autopilot is required for RNAV operations with an RNP of 1.0 NM or less.*
>
> *Use of the autopilot is not authorized for takeoff or landing.*
>
> *Minimum altitude for autopilot disengagement during approach—50 ft below DA/DDA, but no less than 50 ft AGL.*

10.0 RNP Approach and Training

In accordance with the FOM, an arrival briefing was to be completed by the crew prior to the top of descent point. The FOM included guidance to flight crews for briefing and preparing for an instrument approach. The FOM stated in part[36]:

> ***(PF) If planning an RNAV (RNP) or RNAV (GPS) approach, program the FMC and brief additional RNAV approach procedures (-300/-500: N/A).***
>
> *The RNAV Reference Card may be used to assist meeting the programming and briefing requirements.*

The RNAV Reference Card was a two sided laminated checklist, approved by the FAA, and carried on the flight deck. A copy of the RNAV Approach Reference Card was included in the FOM Appendix, Flight Deck Reference Cards, Section 8, page A.8.23[37].

Training for the conduct of RNAV RNP approaches was completed during step 4 of the transition to the use of automation. 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. According to the Step 4 simulator profile, the following RNP approaches were flown: IAD RNAV RNP Z Runway 19L, DAL RNAV RNP Runway 31L, DAL RNAV RNP Runway

[36] Southwest Airlines FOM, Normal Operations, page 3.9.16.
[37] See Attachment 5 – RNAV Approach Reference Card.

13L, and DAL RNAV RNP Runway 13R.[38] Recurrent training was conducted every six months for captains and every 12 months for first officers and pilots flew the BFI RNAV Z Runway 13R approach as one of the two non precision approaches required during this simulator training.

10.1 Stabilized Approach Criteria

Stabilized approach criteria was included in the FOM and varied depending upon the type of approach to be flown. At the time of the incident, the stabilized approach criteria included the following guidance[39]:

- ***By 1,000 ft above TDZE, the aircraft must be in the planned landing configuration (landing gear down and landing flaps)***

  For non-ILS instrument approaches, the aircraft must be in the planned landing configuration by the final approach segment

Interviews with the Manager of Procedures indicated that the stabilized approach criteria had been amended after the incident (but not as a result of this incident) so that on all approaches with vertical guidance, aircraft must be in the planned landing configuration by 1,000 feet rather than by the final approach fix.

The captain said that he did not believe they were fully configured prior to the final approach fix but he thought they had met the stabilized approach criteria by the time they reached the 1,000 foot point.

The FOM Chapter 3, Section 18, pages 3.18.7 – 3.18.8 described callouts and checklist procedures required when descending through 1,000 feet on approach. The FOM stated:

> **No later than 1,000 ft above TDZE and after landing flaps are set, complete the Before Landing Checklist.**
>
> **At 1,000 ft above TDZE:**
>
> **(PF) Call, "1,000 ft, airspeed ____, sink rate ____."**
>
> If stabilized approach criteria are not met, initiate a go-around/missed approach.
>
> **(PM) Call, "1,000 ft."**
>
> If stabilized approach criteria are not met, direct a go-around/missed approach.

[38] See Attachment 9 – Step 4 simulator profile.
[39] Southwest Airlines, Normal Operations, page 3.13.9.

The required callouts on approach were also included in the FOM in table format[40].

The FOM Chapter 3, Section 13, page 3.13.2 included the following guidance on accepting speed assignments from ATC:

> ***Do not accept an ATC approach speed in excess of 170 kt closer than five miles from the end of the runway.***

And;

> *Stabilized approach criteria must be met regardless of the clearance.*

In addition, FOM Chapter 3, Section 18, pages 3.18.2 – 3.18.3 included the following guidance and airspeed table specific to RNP approaches:

> *For RF[41] legs with no chart depicted speed constraints, observe the following maximum speed limitations throughout the RF leg:*

Indicated Airspeed (KIAS)		
Segment	***Indicated Airspeed by Aircraft Category***	
	Category C	***Category D***
Initial & Intermediate (IAF to FAF)	***240***	***250***
Final (FAF to DA)	***140***	***165***
Missed Approach (DA to Missed Approach Holding Point)	***240***	***265***
Airspeed Restriction **May be used to reduce turn radius*	***As specified***	

11.0 CRM Training and Guidance

The current CRM manager has been in the position for about 6 years and was also a captain having been with the airline for about 17 years. Before this position the CRM manager had spent about 8 years as a CRM facilitator for new hire and upgrade programs at the airline.

Four courses were provided at the airline on CRM. These included new hire, upgrade, upgrade leadership, and recurrent. Classes were taught using a mix of lecture and facilitation using one facilitator for each class. The new hire class consisted of a 90 minute segment covering basic communications followed by a full 8-hour day that incorporated cabin crew for a portion of the

[40] See Attachment 8 – RNAV Approach Callouts.
[41] RF – Radius to a Fix legs are curved flight tracks defined by a constant radius to a fix.

day. The course addressed CRM background, effective communications, identifying threats, assessing risks, managing errors, and the use of briefings for effective communications. The upgrade class was a 4 hour ground school followed by an 8 hour upgrade leadership class 6 months later which included cabin crew, dispatchers, maintenance, and ground operations personnel for a 90 minute section of the course. The recurrent ground school course was an 8 hour class for both captains and first officers in which a portion was devoted to CRM training. According to the CRM manager, the amount of time allocated to CRM varied each year based on the events to be covered and was "need based." For example, this year's recurrent class includes 45-60 minutes on CRM focusing on threat and error management (TEM) concepts. This risk resource management module has been taught since January 2011. In addition to the separate courses dedicated to CRM the CRM manager stated that the company is trying to incorporate CRM principles throughout the training process.

The courses used industry accidents and incidents for discussion, including the Comair accident in Lexington, Kentucky and the Southwest Airlines flight 1248 accident at Midway. In addition, incidents or issues arising from data produced by the company's ASAP and FDAP programs were incorporated into the classes.

According to the CRM manager crews discussed managing distractions and preventing breakdowns in performance during their discussion of TEM principles. Guidance provided during this part of the course was to first identify the threat, then use risk assessment in order to manage it. They use NASA's communications model which stated to say something, challenge, then act. They try to integrate that into their operational philosophy to mitigate risk. Included in the threats identified during the TEM discussion is automation. They instruct crews to counter this threat through effective cross check and challenge, and effective monitoring. The CRM manager stated that teaching specific strategies to improve monitoring performance by the pilot monitoring has always been one of their biggest human performance challenges, but they are trying to address it in the risk and resource management module. Another threat discussed in the class is stress and distractions from personal issues. Crews are taught to use basic CRM techniques to manage outside stressors like fatigue, personal stress or any task loading or other crew factors.

12.0 Fleet Differences and Training

At the time of the incident, the fleet included 737-300, 737-500, and 737-700 airplanes with a mix of automation systems and flight deck instrumentation. The -300 and -500 were equipped with electric and pneumatic analog flight instrument systems while the -700 airplanes were equipped with an electronic flight instrumentation system (EFIS) with 6 flat panel liquid crystal displays including 2 PFD's and 2 ND's which provided flight and navigation information in a digital format.

Flight crew training, checking, and currency requirements applicable to flight crews operating different model 737 airplanes were directed by the Flight Standardization Board Report (FSB)[42] and additional guidance for operators was provided in Advisory Circular 120-53A[43].

[42] *Boeing B737-100, -200, -300, -400, -500, -600, -700, -800, -900, -900ER*, revision 12 of Flight Standardization

Southwest Airlines designated the B737-700 as the Base Aircraft[44] and the FOTM included an Operator Differences Requirements (ODR) table which specified the method of compliance and the level of training, checking, and currency applicable to fleet differences.

13.0 Aviation Safety Reporting System (ASRS) Reports

Database search requests were submitted to NASA's ASRS program for reports discussing to 1) landing configuration or roll-out issues involving the B737 speed brake related incidents involving flight crew human performance issues; and 2) RNP related incidents. No incidents relevant to the circumstances of this event were identified related to speed brake arming. Of the seven incidents related to RNP identified in the search,[45] three described confusion, automation management, and situational awareness issues while flying RNP procedures, and one described challenges associated with ATC speed and altitude clearance incompatibilities with an RNP approach.

14.0 Previous Recommendations and Guidance

Following the landing overrun accident of American Airlines flight 1420 in Little Rock, AR on June 1, 1999, the NTSB issued recommendations A-10-49 and A-01-50 regarding the arming, verification, and deployment of ground 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 120-71A which included guidance to operators on the arming of spoiler systems and the flight crew callouts for

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Board Report (Washington, DC: U.S. Department of Transportation, Federal Aviation Administration, December 11, 2009).

[43] Advisory Circular (AC) 120-53A, *Guidance for Conducting and Use of Flight Standardization Board Evaluations*, issued October 15, 2008.

[44] As defined by AC 120-53A, a Base Aircraft is one designated by an applicant and used as a reference to compare differences with another.

[45] See Attachment 6 – ASRS Database Search.

spoiler deployment on landing. AC120-71A[46] 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*[47], included an example which indicated the pilot monitoring should make a "no spoilers" callout if appropriate.

15.0 FAA Oversight

A review of FAA's National Program Tracking and Reporting Subsystem (NPTRS) revealed that during oversight of Southwest Airlines Inc. in the most recent full calendar year (2010) prior to the incident, the FAA conducted the following records of activity:

- 1 inspection pertaining to Technical Staff Administrative Functions.
- 491 inspections pertaining to Organization Technical Administration.
- 1260 inspections pertaining to Surveillance.
- 558 inspections pertaining to Investigations.
- 32 inspections pertaining to General Technical Functions.
- 2 inspections pertaining to Aviation Education and Safety Promotion
- There were no inspection records that pertained to the accident F/O and there was 1 inspection record that pertained to the accident captain. This was a normal oversight inspection with no remarkable comments.

F. LIST OF ATTACHMENTS

Attachment 1: Interview Summaries
Attachment 2: Flight Release
Attachment 3: OPC Landing Output
Attachment 4: Landing Distance Increase
Attachment 5: RNAV Approach Reference Card
Attachment 6: ASRS Database Search

[46] Advisory Circular (AC) 120-71A, *Standard Operating Procedures For Flight Deck Crewmembers*, issued February 27, 2003.
[47] AC120-71A.

Attachment 7: Approach Chart
Attachment 8: RNAV Approach Callouts
Attachment 9: Step 4 Simulator Profile
Attachment 10: Flight Crew Statements

Submitted by:

_____	_____
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July 31, 2011	July 31, 2011