



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Washington, D.C. 20594

December 7, 2020

Group Co-Chairmen's Factual Report

OPERATIONAL FACTORS/HUMAN PERFORMANCE

DCA19IA036

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A. INCIDENT

Operator: Southwest Airlines
Location: Burbank, California
Date: Dec 6, 2018
Time: 0905 Pacific standard time (PST)¹, 1705 UTC (Z)
Airplane: Boeing 737-700, registration N752SW

B. OPERATIONAL FACTORS / HUMAN PERFORMANCE GROUP

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C. SUMMARY

On December 6, 2018, at 0905, Southwest Airlines flight 278, a Boeing 737-700, overran runway 08 during the landing roll at Bob Hope Airport (KBUR), Burbank, California, and came to rest in the engineered materials arresting system (EMAS²) at the departure end of the runway. The two certificated airline transport pilots, three cabin crewmembers, and 112 passengers were not injured and evacuated the airplane via airstairs. The airplane sustained minor damage. The regularly scheduled domestic passenger flight was operating under the provisions of 14 *Code of Federal Regulations (CFR)* Part 121. Instrument flight rules conditions prevailed at the airport at the time of the incident, and an instrument flight rules flight plan was filed for the flight, which originated at Metropolitan Oakland International Airport (KOAK), Oakland, California, about 0810.

¹ All times in the report are PST unless otherwise noted.

² According to the FAA, EMAS uses crushable material placed at the end of a runway to stop an aircraft that overruns the runway. The tires of the aircraft sink into the lightweight material and the aircraft is decelerated as it rolls through the material.

D. DETAILS OF THE INVESTIGATION

December 14, 2018

The group members conducted telephone interviews of the captain, first officer (FO), and the flight dispatcher. The summaries of the flight crew interviews are in attachment 1. The summary of the dispatcher interview is in attachment 2.

October 8-10, 2019

The group members conducted interviews in Dallas, Texas of the following FAA and Southwest Airlines (SWA) individuals:

FAA Supervisory Principal Operations Inspector for Southwest Airlines;
FAA B-737 MAX Aircrew Program Manager, Southwest Airlines Certificate Management Office;³
FAA Aviation Safety Inspector (Dispatch), Southwest Airlines Certificate Management Office;
Director of Flight Operations Training, Southwest Airlines;
Senior Manager of Procedures, Southwest Airlines;
International Programs Manager, Network Operations Center, Southwest Airlines;
Senior Manager of Dispatch, Training and Standards, Southwest Airlines

The transcripts of the SWA interviews are in attachment 2. The transcripts of the FAA interviews are in attachment 3.

E. FACTUAL INFORMATION

1.0 History of Flight

The captain checked in for the flight at 0650. The required report time was 0710. The First Officer (FO) reported about 0640. Preflight activities were normal, and the flight departed on-time at 0810. The captain was the pilot flying (PF) and the FO was the pilot monitoring (PM). The flight was scheduled to arrive at KBUR at 0920. The FO stated that they were ahead of schedule. At 0822, the crew sent a request for the KBUR weather via ACARS⁴. In response they received KBUR ATIS⁵ information H. This ATIS was issued at 0753. The ATIS indicated a wind from 280° at 5 knots, with 1- and 1/4-mile visibility, heavy rain, and a cloud ceiling of 1100 feet. This was the sole weather request made by the crew via ACARS. At 0824, the crew requested and received (via ACARS) a PWB System Landing Data report. (See section 8 for a description of the PWB System

³ This individual served as the FAA's Certification Program Manager for Southwest Airline's transition from their previous performance calculation system (OPC) to the Performance Weight and Balance (PWB) system.

⁴ Aircraft Communications Addressing and Reporting System is a digital datalink system for transmission of short messages between aircraft and ground stations via VHF airband radio or satellite.

⁵ Automated Terminal Information Service is a continuous VHF broadcast of recorded information, including weather information, at selected high-activity airports.

and the Landing Data report for this flight.) The landing report was based on wind from the most recent METAR⁶ available at the time the report was calculated, aircraft estimated landing weight, flap setting, and runway condition. The report indicated that the crew should use autobrakes set at max for the landing, and for the planned runway 08, the airplane would have a stopping margin of 245 feet.⁷ Runway 08 was 5802 feet long. The captain stated that he had never seen a stopping margin from the PWB system that was this low. The FO stated that Burbank always has a low number for stopping margin. He stated that a less than 500-foot margin concerned him. The crew each considered this a low number, and the captain asked the FO to brief the flight attendants and passengers to expect stronger than normal braking after the airplane touched down.

According to the ATC Specialist Report for this incident, at 0848 an ATC controller advised the flight that there was moderate to extreme precipitation around the airport. At 0851 the flight was directed to descend to 8000 feet, and to expect the ILS Z RWY 08 approach at KBUR, shown in Figure 1.

⁶ METARs are hourly surface weather observations at select airports.

⁷ See section 8.1 for a description of stopping margin.

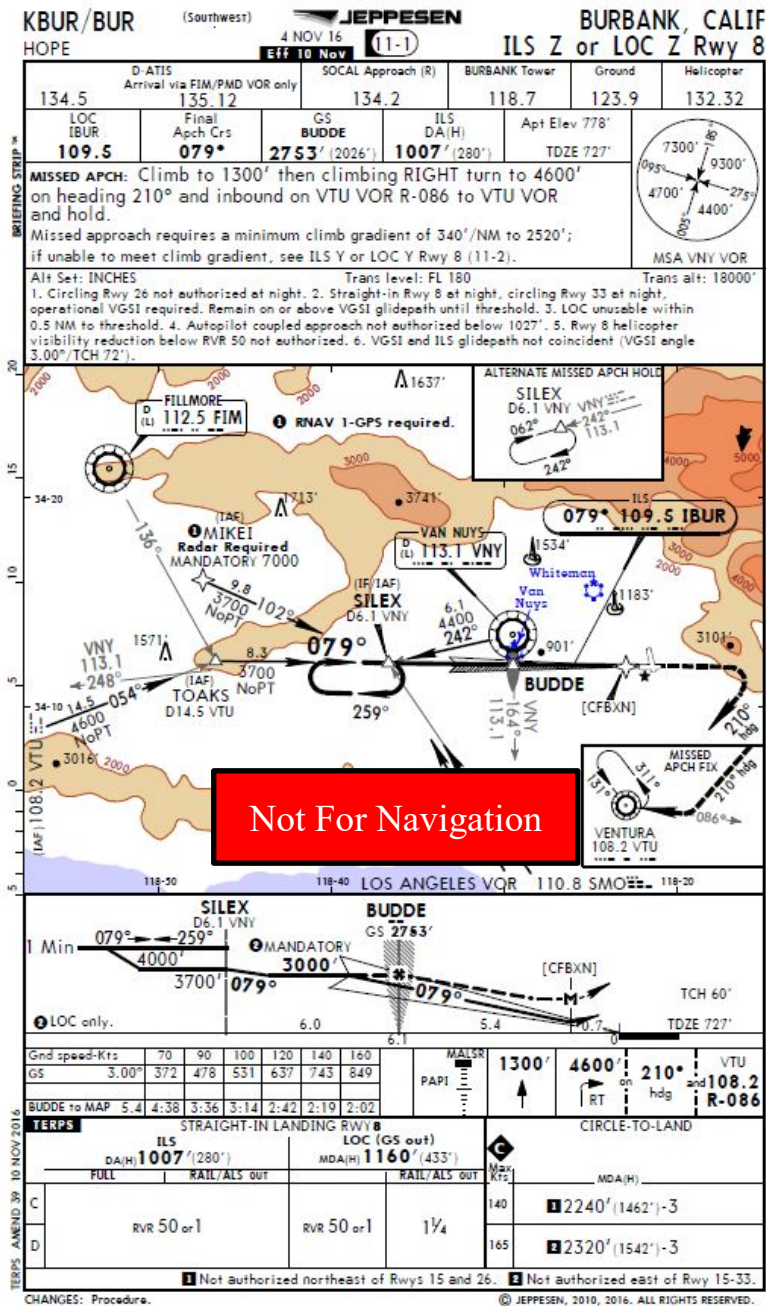


Figure 1: KBUR ILS Z RWY 8 approach procedure. Source: Southwest Airlines

The flight crew acknowledged, and advised they had received ATIS information H. Two minutes later, the flight was cleared for the approach upon reaching MIKEI, an initial approach fix for the approach. At 0855, the ATC controller advised the flight that a plane had reported a 15-knot loss of airspeed on final at KBUR about 10 minutes earlier. The controller also advised the flight that a corporate jet had just conducted a go-around at KBUR. The FO stated that following the loss of

airspeed report from ATC, he was looking for but did not observe any loss of airspeed. In his interview (attachment 1), he stated that the ride was uneventful and relatively smooth. They had anticipated some turbulence on the arrival, but there wasn't much. Nothing was rushed on the approach. The V_{REF} speed was calculated by the PWB system to be 126 KIAS⁸, and V_{TARGET} was to be 131 KIAS⁹. At 0856, another Southwest flight checked in on the same frequency that SWA 278 was on. That flight also advised they had ATIS H. The controller advised him that ATIS J had just become current, and the flight acknowledged. One minute later, the controller advised both SWA 278 and the other Southwest flight that the corporate jet had conducted a go-around because of wind. Both SWA flights acknowledged that message. According to the Flight Data Recorder Specialist Report, about 0858 SWA 278 turned onto its final heading and captured the glideslope and localizer for the ILS approach. Final flaps (40) were selected at 0859, and the indicated airspeed slowed to 133-136 knots. At 0859 the controller in the tower at KBUR cleared the flight to land on runway 08. He also advised the flight of medium to heavy precipitation between the flight and the airport, and that the wind was 260° at 9 knots. The flight acknowledged the transmission. At 0900, the tower controller advised the flight that braking action was reported good 10 minutes earlier by a Boeing 737. The controller also advised of heavy precipitation directly over the airport. The flight acknowledged the message. At 0901, the tower controller broadcast the wind as 270° at 10 knots. One minute later the tower controller broadcast the final wind check given before the incident, 270° at 11 knots. No acknowledgment of these two final transmissions from the tower was heard from SWA 278.

The interviews indicated that they discussed the final wind they received, 270° at 11 knots, and agreed that the resulting tailwind component was within the limit of 10 knots shown in the Limitations section of the SWA B737NG Aircraft Operating Manual (AOM).

The captain (PF) reported that around 400 ft. above ground level (agl), the flight broke out of the clouds, and he had a clear picture of the runway. At this point, he stated that glideslope and throttles were "right on", and that he had an awareness of the 1000-foot runway markers as he crossed the runway threshold. His speed at this point was between 131 and 133 knots. At the decision altitude for the approach, 280 ft., he disconnected the autothrottles and the autopilot, and descended using the PAPI¹⁰ lights as a descent-path reference. The FO stated that after the disengagement of the autopilot, the captain made a slight correction to the left to line up with the centerline. The FO also stated that at that point, the airplane was slightly high, the captain corrected, and then they were slightly low on the glidepath. The FO stated that the flight crossed the threshold between the 30-

⁸ Knots indicated airspeed; the speed displayed to the pilots.

⁹ V_{REF} is a speed determined by the manufacturer for flying an approach. It is variable based on landing weight, airport elevation, and aircraft configuration (flap setting). It is the required speed at the 50-foot height above the threshold end of the runway if the aircraft is to obtain calculated landing performance. V_{TARGET} is a speed defined in SWA B737NG Aircraft Operating Manual (AOM) as a PWB System-computed speed that is V_{REF} plus on-half the headwind component plus full gust component. It has a minimum value of V_{REF} plus 5 knots. Section 10.7.2 of the AOM contains a note which states for tailwind landings, V_{TARGET} should be V_{REF} plus 5 knots.

¹⁰ Precision Approach Path Indicator lights can be a component of an airport's approach light system. They primarily assist landing aircraft by providing visual glide slope guidance in non-precision approaches environment.

and 50-foot calls of the EGPWS¹¹. The NTSB Performance Study for this incident states that the airplane crossed the threshold at an altitude of 54 feet and a speed of 137 KIAS.¹² In the landing flare, at about 5 ft. agl, the captain noted that rain intensity “picked up and visibility decreased a little bit.” He reported he touched down between 1300 and 1500 feet from the runway threshold. The FO stated they touched down in the touchdown zone, which he defined as 1000-1500 feet from the threshold. The Performance Study indicated the airplane touched down about 2504 feet from the threshold at a speed of 126 KIAS. The ATC Specialist Report stated that a controller in the tower observed the touchdown near where taxiway D7 intersected the runway, about 2600 feet from the threshold. See Figures 2 and 3 for the location of the taxiway and the 1000-foot markers on runway 08.

In his statement, the FO said that the speedbrakes and thrust reversers were deployed immediately on touchdown. He reported that the brake anti-skid system began to cycle, and the airplane did not slow appreciably at first. The captain stated that after touchdown, he used maximum reverse thrust and heard and felt chattering of the brakes through the brake pedals. He verified that the speedbrake handle was extended and “started blending in manual brakes after that.” He stated that with thrust reverse and autobrakes, the airplane did not feel like it was slowing. It then started to slow, but then deceleration decreased. As the airplane passed the intersection of runway 15/33 (about 3765 ft. from the runway 08 threshold) he became concerned about stopping. He stated that on a dry day, you could stow the thrust reversers and ease off the brakes at that point. He guessed that the airplane was at 70-80 knots at this point, faster than on a dry day. As they approached the final 1000-500 feet of the runway, the deceleration slowed markedly. He saw the large intersection where taxiway D1 intersected with the runway (about 5340 feet from the runway threshold) and thought he might be able to make a turn off the runway there, but as he tried to turn using left rudder and the tiller, he didn’t feel the airplane was responding. He felt the nosewheel was just skidding. He stated he then straightened out the nosewheel so they would not enter the EMAS with the nosewheel cocked sideways. The airplane entered the EMAS at a speed of about 10-15 knots and was quickly brought to a stop. The thrust reversers were still engaged upon entry.

2.0 Flight Crew Information

The incident flight crew consisted of a Captain and an FO.

2.1 The Captain

2.1.1 The Captain’s Pilot Certification Record

FAA records for the Captain indicated the following:

¹¹ Enhanced Ground Proximity Warning System. This system can provide automatic callouts of airplane height above ground level during the final phase of landing.

¹² The ILS Z Runway 08 approach procedure at KBUR (Figure 1) notes a threshold crossing height (TCH) of 60 feet if following the 3-degree glideslope.

Commercial Pilot – Airplane Single Engine Land; Rotorcraft-Helicopter; Instrument Airplane and Helicopter certificate issued September 14, 1985.

Airline Transport Pilot – Airplane Multiengine Land; Commercial Privileges Airplane Single Engine Land; Rotorcraft-Helicopter; Instrument Helicopter certificate issued August 29, 2004.

Airline Transport Pilot – Airplane Multiengine Land, B-737; Commercial Privileges Airplane Single Engine Land; Rotorcraft-Helicopter; Instrument Helicopter certificate issued March 6, 2005.

2.1.2 The Captain’s Certificates and Ratings Held at Time of the Incident¹³

AIRLINE TRANSPORT PILOT (issued March 6, 2005)

Airplane Multiengine Land

B-737

Commercial Privileges Airplane Single Engine Land; Rotorcraft-Helicopter
Instrument Helicopter

MEDICAL CERTIFICATE FIRST CLASS (issued October 22, 2018)

Limitations: Must wear corrective lenses.¹⁴

2.1.3 The Captain’s Training and Proficiency Checks Completed¹⁵

Date Upgraded to Captain on B-737	March 9, 2016
Date of Initial Type Rating on B-737	March 6, 2005
Date of Most Recent AQP ¹⁶ Evaluation Event (LOE)	February 23, 2018
Date of Most Recent AQP Training Event (MO)	February 22, 2018
Date of Most Recent PIC Line Check	April 6, 2018

2.1.4 The Captain’s Flight Times¹⁷

The Captain’s flight times:

Total pilot flying time	15,410 hours
Total PIC time	4,995 hours

¹³ Source: FAA.

¹⁴ In his interview, the captain stated he was wearing his glasses during the incident approach.

¹⁵ Source: Crew training records received from Southwest Airlines

¹⁶ Advanced Qualification Program. This was Southwest Airlines Flight Training Program; According to the Southwest Airlines AQP Manual, the program required pilots to complete a Maneuvers Observation (MO) and a Line Oriented Evaluation (LOE) each calendar year.

¹⁷ Flight times provided by Southwest Airlines.

Total B-737 time	11,350 hours
Total B-737 PIC time	2,350 hours
Flight time last 90 days	247 hours
Flight time last 30 days	30 hours
Flight time last 24 hours	0 hours

2.1.5 The Captain's 72-Hour History

On Sunday, December 2, he completed a trip and commuted home for two days off.

On Monday, December 3, he ran errands with his wife. On Tuesday, December 4, he took their dogs for walks with his wife.

On Wednesday, December 5, he checked in around 1130 for a 1300 commercial flight from Portland to Oakland. He arrived in Oakland about 1440, ate a lunch and left the airport about 1530-1600. He arrived at the hotel, set up his uniform and went to bed about 2130-2140.

On Thursday, December 6, the day of the incident flight, he awoke at 0530 and took the 0630 hotel van to the airport. He arrived at the gate about 0730 which was 10 minutes before gate show time. He reported that he slept fine the night before the incident flight.

2.1.6 The Captain's Background

The captain was 58 years old. He had attended the University of Washington. He had retired from the US Marine Corps in 2005 after 23 years of service. During his time in the Marine Corps, he had flown and instructed in EA6B and T2 aircraft. He had started at Southwest Airlines in January of 2006 and had upgraded to captain in March of 2016.

A search of the FAA's Accident/Incident Data System and the Enforcement Information System revealed no records pertaining the captain.

2.1.7 The Captain's Personal Information

The captain lived in Camas, WA. He generally went to bed about 2230 or 2300 and awoke at 0630 to walk his dog as the sun rose. He estimated this was his schedule for the days he was home prior to the incident. He typically needed about 7-8 hours to feel rested, with a minimum of 6 to 6.5 hours and typically shoots for 7 to 7.5 hours of sleep. He considered himself to be a morning person and had no history of sleep disorders.

He had no major changes in his life in the past year. He described his health as excellent and stated he had never taken a sick day. He had no issues with color vision and described his hearing as

normal. He did not take prescription medications, drink alcohol, smoke, use illicit drugs, or take any medications in the previous 72 hours that could have impacted his performance.

The incident FO described the captain as a “fantastic guy” and enjoyed flying with him. He described the captain’s CRM skills as “top notch” and said he’d have no problem bringing up concerns to the captain and felt that the captain was open to his suggestions as well. When asked to describe the captain’s proficiency, he stated that the captain flew “a really great jet.”

2.2 The First Officer

2.2.1 The First Officer’s Certification Record

FAA records for the FO indicated the following:

Commercial Pilot – Airplane Multiengine Land; Instrument Airplane; Multiengine limited to centerline thrust certificate issued December 3, 1990

Commercial Pilot – Airplane Single and Multiengine Land; Multiengine limited to centerline thrust; Instrument Airplane certificate issued June 21, 1991.

Commercial Pilot – Airplane Single and Multiengine Land; B-707, B-720; Instrument Airplane certificate issued June 21, 1991.

Airline Transport Pilot – Airplane Multi Engine Land B-707, B-720; Commercial Privileges Airplane Single Engine Land certificate issued June 11, 2000.

Flight Instructor – Airplane Single Engine; Instrument Airplane certificate issued July 1, 2011, renewed July 30, 2013, July 20, 2015, June 9, 2017

Airline Transport Pilot – Airplane Multi Engine Land B-707, B-720, B-737; Commercial Privileges Airplane Single Engine Land certificate issued December 9, 2011.

2.2.2 The First Officer’s Certificates and Ratings Held at Time of the Incident¹⁸

AIRLINE TRANSPORT PILOT (issued December 9, 2011)

Airplane Multiengine Land

B-707; B720; B-737

Commercial Privileges Airplane Single Engine Land;

FLIGHT INSTRUCTOR (June 9, 2017)

Airplane Single Engine; Instrument Airplane

¹⁸ Source: FAA

MEDICAL CERTIFICATE FIRST CLASS (issued October 1, 2018)

Limitations: Must wear corrective lenses.¹⁹ Not valid for any class after 10/31/2019.

2.2.3 The First Officer's Training and Proficiency Checks Completed²⁰

Date of Initial Type Rating on B-737	December 9, 2011
Date of Most Recent AQP Evaluation Event (LOE)	September 30, 2018
Date of Most Recent AQP Training Event (MO)	September 29, 2018
Date of Most Recent Line Check	February 21, 2012

2.2.4 The First Officer's Flight Times²¹

The incident FO's flight times:

Total pilot flying time	20,855 hours
Total PIC time	4,400 hours
Total flying time B-737	5,000 hours
Total B-737 PIC time	0 hours
Flight time 90 days	208 hours
Flight time last 30 days	28 hours
Flight time last 24 hours	0 hours

2.2.5 The First Officer's 72-Hour History

On Monday, December 3, the FO completed the last day of a trip and arrived in Oakland between 1500-1600. He then drove to Richmond, CA to stay with friends.

On Tuesday, December 4, he attempted to go sailing. He estimated he went to bed about 2200-2230.

On Wednesday, December 5, he woke about 0700. During the day he spent time with his friends and went to bed by 2100.

¹⁹ In his interview, the FO stated he wore reading glasses during the day, and glasses for distance during flight. He was wearing his reading glasses at the time of the incident.

²⁰ Source: Crew training records received from Southwest Airlines.

²¹ Flight times provided by Southwest Airlines and the First Officer.

On Thursday, December 6, the day of the incident, he awoke about 0500 and drove to the airport. He drank coffee and ate breakfast before the flight and arrived at the aircraft about 30 minutes prior to show time. He reported feeling rested and alert the morning of the incident flight.

2.2.6 The First Officer's Background

The First Officer was 53 years old. He had been in the military for 25 years, and had flown KC135, U2, and T-38 aircraft. He had left the military in August of 2001 and joined American Airlines. Three weeks into his training, 9/11 happened. He left American Airlines and he re-entered the military for ten more years. He joined Southwest Airlines in January of 2012.

A search of the FAA's Accident/Incident Data System and the Enforcement Information System revealed no records pertaining to the FO.

2.2.7 The First Officer's Personal Information

The FO stated he needed between 6-8 hours of sleep in order to feel rested and aimed for 8 hours. He described himself as a morning person and tried to bid morning flights for that reason. He had no history of sleep disorders and described his health as "good." He reported having normal color vision and used corrective lenses for both near and distant vision and was wearing reading glasses during the incident. He drank alcohol occasionally and the last time he consumed alcohol was a glass of wine the night prior to the flight. He did not smoke tobacco or use illicit drugs and did not take any medication in the 72 hours prior that would have affected his performance during the incident flight.

The incident captain described the FO as "awesome" to fly with adding that it was like flying with another captain. He said the FO was even-tempered and would bring up concerns if they arose.

3.0 Medical and Pathological Information

Following the incident, the pilots received drug and alcohol testing in accordance with 14 *CFR* Part 120. All results were negative.

4.0 Aircraft Information

The incident airplane was a Boeing 737-700, Registration N752SW, serial number 29804. At the time of the incident, it had a total of 68,280 airframe hours. The registered owner was Southwest Airlines. It held a transport category airworthiness certificate dated January 22, 2016. At the time of the incident, the airplane had 1 MEL (minimum equipment list) deferral. The deferral was not for an item relative to this incident.



Photo 1: The incident airplane (Source: Jetphotos.net)

4.1 Tailwind Landing Limitation

According to section 3.2.7 of the AOM, the aircraft had a 10-knot limit for tailwind during takeoff and landing.

4.2 Weight and Balance Information

Southwest Airlines provided the following information, except for the Takeoff CG limit information, which was taken from the Boeing 737 Airplane Flight Manual.

WEIGHT & BALANCE / PERFORMANCE (maximum weights in bold)		
	Operating Empty Weight (OEW)	84,835 lbs.
	Cargo / baggage	1,005 lbs.
	Flight Attendants	630 lbs
	Passenger weight	21,840 lbs.
	Zero Fuel Weight (ZFW)	108,310 lbs.
	Fuel	17,700 lbs.
	Taxi fuel burned	300 lbs.
	Takeoff Weight	125,710 lbs.

Maximum Takeoff Weight	154,500 lbs.
Planned landing weight (ATL)	120,800 lbs.
Maximum Landing Weight	128,000 lbs.
Center of Gravity (CG) (% MAC)	22.8
Takeoff CG limits (% MAC)	14.0-28.5

Table 1: Aircraft Weight and Balance Information

5.0 Meteorological Information

The following weather information is from METAR and SPECI ²² reports surrounding the time of the incident. (The METAR and SPECI weather observations below are decoded and shown in plain language.)

- 0753 (1553Z METAR) wind 290° at 5 knots, one and one-quarter mile visibility, heavy rain, mist, broken cloud layer at 1100 ft. agl.
- 0841 (1641Z SPECI) wind 260° at 11 knots, two and one-half miles visibility, rain and mist, few clouds at 400 ft. agl, broken cloud layer at 1300 ft. agl.
- 0853 (1653Z METAR) wind 280° at 11 knots, one and one-half mile visibility, heavy rain, mist, few clouds at 400 ft. agl, overcast cloud layer at 1300 ft. agl.
- 0905 Incident
- 0915 (1715Z SPECI) wind 290° at 8 knots, one-mile visibility, heavy rain, mist, few clouds at 500 ft. agl, broken layer of clouds at 1300 ft. agl.

The source of these weather observations is the Weather Study for this incident.

According to KBUR ATIS history information received from SWA, the following ATIS messages were in effect at the time indicated.

- ATIS H effective at 1553Z and containing weather information based on the 1553Z METAR.
- ATIS I effective at 1641Z and based on the 1641Z SPECI.
- ATIS J effective at 1641Z identical to ATIS I except for the inclusion of a wind shear advisory²³.
- ATIS K effective at 1653Z and based on the 1653Z METAR. This ATIS also included wind shear advisories.

²² A SPECI report is a type of METAR issued on a special non-routine basis as dictated by changing meteorological conditions.

²³ According to FAA Order JO7110.65T, Air Traffic Control, paragraph 3-1-8, a statement must be included on the ATIS for 20 minutes following the last report or indication of wind shear/microburst.

6.0 Airport Information²⁴

The KBUR airport was located in Burbank, California. The airport had two runways, 08/26 and 15/33. Runway 08/26 was 5802 ft. in length and had an EMAS installed at the departure end of runway 08. Runway 08 was the only runway at the airport served by a precision instrument approach. About the first 490 feet of runway 08 is concrete and is distinctly lighter in appearance than the remaining runway, which is asphalt. This difference can be seen in Figure 3. The runway was grooved.



Figure 2: KBUR Airport Diagram excerpt. Source: FAA

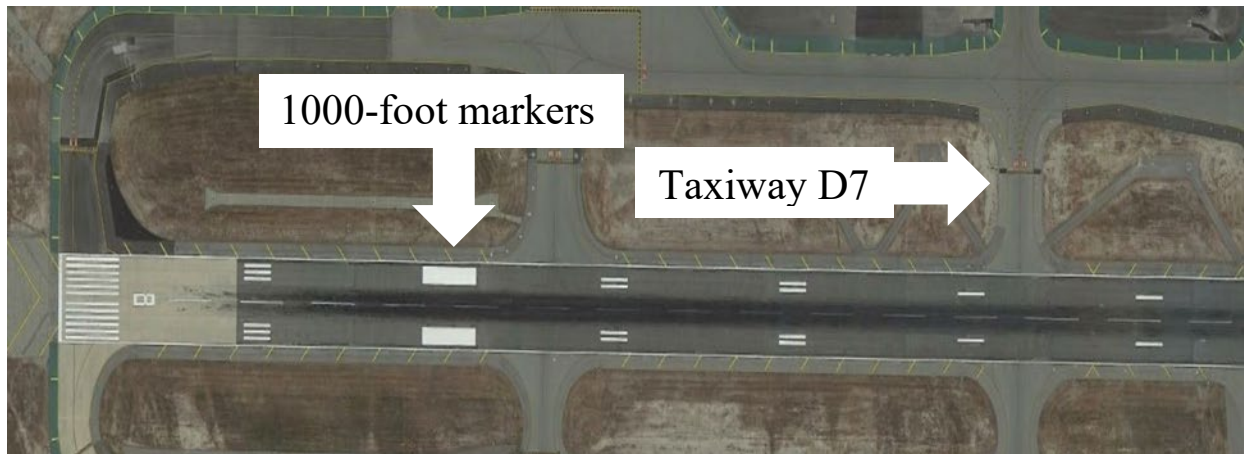


Figure 3: KBUR Runway 08 segment. Source: Google Earth

²⁴ Source: FAA Chart Supplement for KBUR.
OPS/HP FACTUAL REPORT

7.0 Organizational and Management Information

7.1 Company Training

7.1.1 Crew Resource Management Training

Southwest used the risk and resource management (RRM) framework to integrate human factors, technical skills, and effective resource management to assist in time-critical decision making. Risk factors were organized into categories related to task loading, additive conditions, and crew factors with the goal to maintain operation in “the green” risk level in operations which represented a high likelihood of a positive outcome. According to the Advanced Qualification Program Manual (AQPM), “this is a combination of good situational awareness, management strategies, and resources in place to capture errors. Effective communication assists proactive management to anticipate problems, minimize errors, and provide enhanced situational awareness, and balance operational priorities.” The framework incorporated 5 organizational controls against risk:

1. “Knowledge, Skills & Techniques
2. Briefings and External Resources
3. Automation
4. Checklists
5. Policies, Procedures, and Flows.”

The airline integrated RRM throughout organization processes and operational training. Specific ground modules in RRM were incorporated in initial qualification ground training (up to 8 hours) and continuing qualification (up to 3 hours) via distance learning, maneuvers observation, and LOE per their AQPM.

The incident captain completed RRM ground training during initial training in 2006, during an operational philosophy seminar in 2015, and during upgrade training in 2016. The incident first officer completed RRM ground training during initial training in 2012 and during an operational philosophy seminar in 2015.

7.1.2 Performance Weight and Balance (PWB) System Training

The SWA Flight Operations Training Manual (FOTM) lists PWB System training for pilots under section 7.5.2 *Ground Training Outline* (for new-hire B737 SICs). In the outline, the topics include *Performance Weight and Balance (PWB) Training* and *Use of Performance Weight and Balance (PWB) System for Adjustments*. Section 9.2.3 of the manual contains *General Operational Subjects Training Modules* for the captain upgrade ground training curriculum. One module listed here, *Aircraft Performance*, included *PWB System Training* and *Use of PWB System for Adjustments*.

In the case of the two incident pilots, each had completed their respective training (initial for the FO and upgrade for the captain) prior to the PWB System (landing module)²⁵ entering service at SWA in the second half of 2016.

Documents received from SWA indicated that the *PWB Overview and Landing Module* was a component of SWA recurrent ground training distance learning for 2016. Training records indicated that the captain completed the distance learning element that contained this module on 9/21/2016. The FO completed it on 8/31/2016. Other topics related to the PWB landing module such as brake cooling and PWB non-normals, were included in 2018 recurrent training distance learning.

8.0 Relevant Systems and Procedures

8.1 Performance Weight and Balance System

According to the SWA B737NG AOM, “The PWB system is a real-time performance and weight and balance data computation system used to produce data required to operate an aircraft within the limitations specified in the Airplane Flight Manual CFRs.” The system integrates five technology platforms. These include the interface technologies for dispatchers, operations agents, pilots, and the PWB Data Centers. There are multiple PWB Data Centers for redundancy. The centers are remotely hosted, real-time calculation engines. The pilot’s interface with the PWB Data Center is the ACARS. Among other functions, this interface is used in-flight for crews to obtain time of arrival landing performance information. A description of crew usage is contained in section 8.2.2.

One product the PWB System produces that crews use in-flight to prepare for landing is the PWB Landing Data report. This report provides the crew with information necessary to determine the suitability of the planned landing runway based on various factors. Key items provided to the crew in the Landing Data report include the speeds the crew should use in the approach and landing (V_{REF} and V_{TARGET}) and the runway stopping margin for the crew’s selected runway.

Stopping margin is the distance between where the airplane should come to a stop, based on PWB System calculations, and the end of the runway. According to the section 17.12 of the SWA B737NG AOM, stopping margins are calculated for three different levels of deceleration as defined by the autobrake system; AB2, AB3, and ABM (autobrakes max)²⁶. The calculation assumes touching down 1500 ft. from the threshold, uses a touchdown speed adjusted for wind, and accounts for the use of reverse thrust at detent position 2 for normal configuration landings²⁷.

²⁵ SWA implemented use the PWB system in two phases. The first, using the PWB landing module only (for landing data calculations) began in late 2016. Full use of the system, including the takeoff module, began in 2017.

²⁶ Deceleration levels of AB2, AB3, and ABM equate to manual braking equivalents of light, moderate, and maximum, respectively. See section 8.2.5 for more information on the use of autobrakes.

²⁷ According to section 12.1.1 of the AOM, stopping margin calculations assume that reverse thrust is selected within two seconds after touchdown, and planned reverse thrust level is attained within eight seconds of touchdown. In this

A 15 percent safety factor is then added to the distance the PWB system calculates is needed for the airplane to come to a stop.²⁸ The stopping margin is the difference between the total calculated landing distance (including the 15 percent safety factor) and the runway length available.

Stopping margins are shown on page 3 of the Landing Data report. An example page 3 is shown in Figure 6.

The Landing Data report is discussed in more detail in section 8.2.2.

8.2 Relevant Procedures

8.2.1 Dispatch Use of the PWB System

According to the SWA Dispatch Operations Manual, the flight dispatcher would use the PWB System to generate landing performance data for the dispatch release given to the crew. An end product of the dispatch use of the PWB system is a maximum takeoff weight limit that would meet 14 *CFR* Part 121.195. (This regulation requires aircraft to depart at a weight that will allow them to arrive at their destination at a weight which would allow the aircraft to stop within 60 percent of the length of the anticipated arrival runway.) This value is noted on the flight's dispatch release (attachment 5) as the "DISP-WET" condition. The "WET" qualifier indicates that the maximum takeoff weight is calculated to meet the above-noted Part 121.195 requirement for a wet runway, which requires that the runway be 15 percent longer than that required to meet the 60 percent requirement. The 60-percent requirement applies only to dry runways.

If the destination runway is forecast to be anything other than dry, the PWB will provide a takeoff weight limit which would ensure that the same requirement is met considering the specific runway condition code (RCC) anticipated at time of arrival. Based on the forecast and current conditions at the destination airport, the RCC used in the calculation for this flight is 5, and the maximum takeoff weight that will allow the airplane to meet the necessary stopping requirements with an RCC of 5 is shown below the "DISP-WET" line and is labeled "5-GOOD".

Both these limits are shown at the top of page two of the dispatch release for the flight. The maximum takeoff weight shown for both scenarios (DISP-WET and 5-GOOD) is 132,900 lbs. The takeoff weight shown on the dispatch release was 128,200 lbs. The takeoff weight shown on the *Weight and Balance Report* for the flight is 125,710 lbs. This document contains final weight and balance information and is completed after final fuel and payload weights are known.

Both of these maximum takeoff weight calculations, "DISP-WET" and "5-GOOD", were made by the PWB system using an arrival airport wind estimate at time of arrival. Both used a KBUR

section the AOM also states that detent 2 is the reverse thrust lever position for normal landings.

²⁸ FAA SAFO (Safety Alert for Operators) 19001, its predecessor, SAFO 0612, and FAA AC (Advisory Circular) 91-79A all recommend adding a 15 percent safety factor to the actual landing distance determined by a time of arrival performance calculation.

forecast wind of 120 degrees at 8 knots, and use of runway 08 at KBUR. The forecast that contained this wind value was scheduled to become effective at 1900Z, 1 hour and 40 minutes after the scheduled arrival of the flight. The KBUR forecast in effect at the time the flight departed, 1610Z, was for variable wind at 3 knots. These forecasts are shown on the flight's weather packet in attachment 6.

In his interview, the flight's dispatcher did not recall entering the 120 degrees at 8 knots wind. He said usually this is left blank. According to the SWA Dispatch Operations Manual, if this item is left blank, the PWB system uses calm wind for these calculations.

8.2.2 Crew Use of the PWB System for Landing Performance Calculation

SWA uses the PWB System to provide landing data to flights as they approach their arrival airport.

The SWA Flight Operations Manual, section 12.1, requires that a landing distance assessment be made within one hour of ETA. According to AOM section 10.7.1, crews are expected to use the PWB System to acquire and review PWB Landing Data before beginning a descent for landing. Section 10.4 of the Southwest Flight Operations Manual (FOM), *Before Top of Descent Tasks*, lists "evaluate landing performance" as one of these tasks.

Crews accomplish this task by following the *PWB Normal Landing Planning Procedure* outlined in section 17.7 of the AOM. This procedure begins with the crew accessing the ACARS PWB Landing Performance Data Module through the MCDU²⁹ keypad. On two pages of the module labeled "LD CONDITIONS", the crew enters data about the known landing conditions, and confirms auto-populated information such as zero fuel weight, arrival fuel, and landing weight. The landing conditions data entered by the crew includes:

- landing airport
- runway
- intended flap setting
- runway braking action
- wind

(Note: There is other data that the crew enters on the two LD CONDITIONS pages, but these listed above are the relevant items for this event.)

According to the AOM, when requesting landing data from the PWB System, wind entries by the crew are optional. They are to be used if the METAR information captured by the PWB System is expired, invalid, or there is a significant change and a new METAR/ATIS has not been issued.

²⁹ Multi-purpose Control and Display Unit
OPS/HP FACTUAL REPORT

Following the entry and verification of data on the two LD CONDITIONS pages, the crew transmits the information to the PWB Data Center via ACARS by selecting the key adjacent to the “SEND” label on the second LD CONDITIONS page. The PWB Data Center performs necessary calculations (using the latest METAR for wind values) and sends a Landing Data return message to the flight that is available for pilot viewing on the MCDU.

The Landing Data is shown on multiple pages on the MCDU, and includes:

- Weather information (wind, temperature, altimeter setting) and runway condition information used in the computation of landing data; (page one and two of Landing Data)
- The time the landing data was computed: (page one of Landing Data)
- V_{REF} and V_{TARGET} speeds: (page three of Landing Data)
- Runway stopping margins for various autobrakes settings which may be used. (page three of Landing Data)

Example pages of the Landing Data report returned to a flight by the PWB System and displayed on the MCDU are shown below. Note: These examples are taken from the SWA AOM. The data they display is not that of the actual event.



Figure 4: PWB System Landing Data page 1. Source: SWA

Page one of the Landing Data (Figure 4) shows the data was computed for a runway at Midway Airport (KMDW), the flight number, the time the data was generated, the wind and other weather information used in the data calculations, and the landing weight.



Figure 5: PWB System Landing Data page 2. Source: SWA

Page two of the Landing Data (Figure 5) shows the runway condition used in the data calculations (5—GOOD indicates a runway condition code³⁰ of 5 with good braking action.) Other items that could be included under the “Remarks” heading, but not shown in this example, are conditions which may have been selected by the crew such as anti-ice options. Other remarks may be included here, such as the requirement for use of autobrakes.

³⁰ According to FAA AC 150/5200-30D, runway condition codes represent the runway condition description based on defined terms and increments and are used by pilots to determine landing performance parameters. The codes range from 0 (zero), indicating a runway contaminated with wet ice, slush over ice, or other contaminants that would lead to minimal or non-existent braking deceleration, to 6, indicating a dry runway.

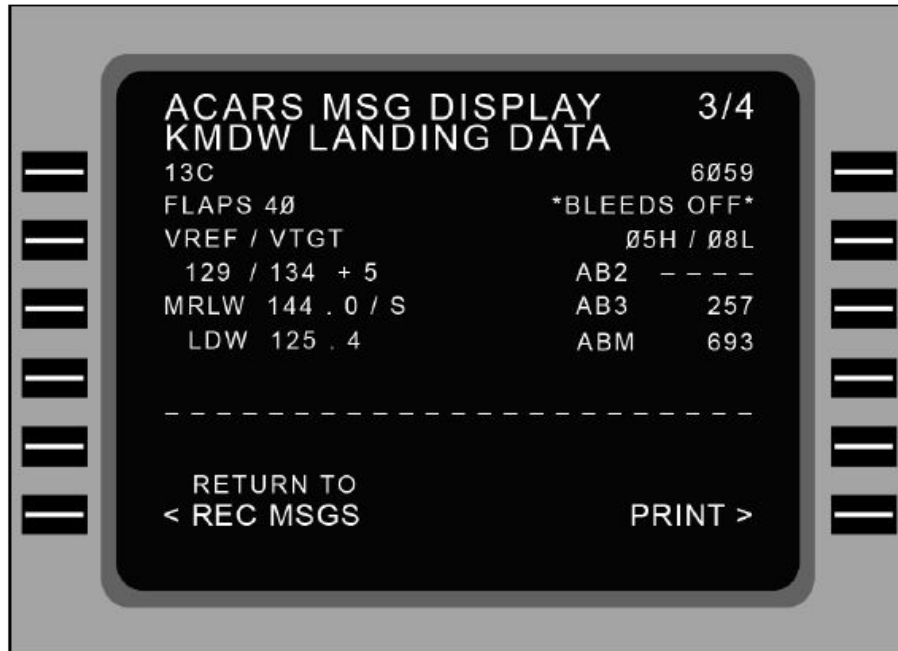


Figure 6: PWB System Landing Data page 3. Source: SWA

Page three of the Landing Data (Figure 6) shows the runway the calculations were performed for (13C), the flap setting the crew planned, the computed V_{REF} and V_{TARGET} speeds (129 and 134), the maximum runway landing weight (MRLW) for that runway, along with a code indicating the reason for the maximum limit (144,000 lbs with a structural (s) limit), the landing weight (LDW) the crew planned (125, 400 lbs), a display of headwind and crosswind components of the wind used in the calculation (5 knot headwind, 8 knot left crosswind), and stopping margins for each of the three autobrake settings the crew could select. In this example, for AB3, there is a 257 ft. margin and for ABM there is a 693 ft. margin. The dashed line next to the AB2 indicates there is no positive stopping margin for the AB2 setting.

Section 12.1 of the AOM provides normal landing procedures. An extract from section 12.1.1 of the AOM, states:

PWB stopping margin information is based on the assumption that aircraft touchdown occurs not later than 1,500 ft from the usable end of the runway. If the aircraft lands beyond the 1,500-ft mark, the PWB System-computed stopping margin will be invalid, and in some cases, the runway length will be insufficient to stop the aircraft.

Later in section 12.1.1, the AOM states:

If touchdown occurs beyond 1,500 ft, the ability to stop on the remaining runway may be compromised. Also, if the current conditions are significantly different than the anticipated conditions at the time of PWB programming (e.g., wet runway vs. dry runway, tailwind vs.

calm wind), the PWB System-computed stopping margin may be invalid. If a landing is made in either of these situations, higher than planned braking may be needed to account for the reduced or insufficient stopping margin. The situation becomes more critical on shorter runways; therefore, a go-around is the better option. A go-around is possible until the thrust reverser levers are raised.

8.2.3 Obtaining In-flight Weather

Section 10.4 of the SWA FOM contained guidance for the Pilot Monitoring to obtain the ATIS information prior to reaching the top of descent. For this flight, the top of descent point was shown on the dispatch release to be about 21 minutes prior to landing. On the release, landing was scheduled to occur at 0912. (The captain noted in his interview the flight was about 10 minutes ahead of schedule.) The Flight Data Recorder Specialist Factual Report for this incident shows the flight began its descent from cruising altitude at 0839. The FOM also stated the following regarding this task:

Do not delay this task to wait for new ATIS at the top of the hour. Experience has shown that weather changes between hourly observations do not have a significant effect on landing performance computations.

According to the ACARS log, the flight left the gate at 0800, and took-off at 0810. The crew requested and received the KBUR weather information at 0822. The weather received was KBUR ATIS information H, which indicated wind of 280° at 5 knots, one and one-quarter miles visibility with heavy rain, and a broken cloud layer at 1400 ft. agl. Also received in this ACARS message was a runway condition report indicating a runway condition code (RCC) of 5-GOOD for runway 08. According to the ACARS message log for the flight at attachment 4, this was the only KBUR weather requested or received by the flight via the ACARS system.

In interviews, the captain stated he was aware of the 280° at 5 knots reported in ATIS H. He did not mention if he was aware of an ATC transmission to another flight that indicated that a more recent ATIS, J, was current. This call to another Southwest flight was noted in the ATC Specialist's Report for this incident. The captain stated in his interview that the control tower informed him of wind of 270° at 11 knots as the flight descended below 1000 ft. agl.

The FO stated the last ATIS they had was ATIS H. He also stated the control tower reported wind of 270° at 11 knots, received by the crew when the airplane was about 1000 ft. agl.

8.2.4 Approach Speeds

Approach speeds, V_{REF} and V_{TARGET} , are returned to the crew from PWB System Landing Data report, via the ACARS system, as described in the previous section. For the incident flight, the data returned is shown on the flight's ACARS message log, contained in attachment 4. The Landing Report returned an indicated V_{REF} speed of 126 knots, and a V_{TARGET} speed of 131 knots.

According to section 10.7.2 of the SWA B737NG AOM, the PWB system defines V_{TARGET} as V_{REF} plus one-half the headwind component plus full gust component but sets a minimum value of $V_{REF} + 5$ knots. A note in this section states, “For tailwind landings, set V_{TARGET} equal to $V_{REF} + 5$ kts.”

Another note in this section states, “The purpose of the +5 knots is to ensure that V_2 is met in case of a go-around. Under adverse conditions, the Captain may elect to fly at V_{REF} ”.

8.2.5 Use of Autobrakes

According to section 3.14.2 of the AOM, autobrakes must be used on any runway that reports an RCC of 5-GOOD or less. Autobrakes use is also required if the Landing Data report from the PWB system specifies they be used, as was the case in this incident, noted in the next section.

The transition from autobrakes to manual braking is addressed in section 12.1.1 of the AOM, which provides the following guidance for the PF:

The intent of using the autobrake system for landing is to let the system automatically brake the aircraft to an appropriate speed, not to override the system shortly after touchdown. Autobrakes 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 speedbrake deployment, reverse thrust application, directional control, and overall stopping performance. Once the landing roll is stabilized, transition to manual brakes by overriding the autobrake system. The speed at which this transition is accomplished will vary with runway and environmental conditions. With adverse conditions, transition at a slower speed. At the appropriate speed, apply and maintain brake pedal pressure to override the autobrake system. Autobrake disarm is indicated by the illumination of the AUTO BRAKE DISARM light and the PM's "autobrake disarm" callout.

8.2.6 PWB Landing Data Report Received by the Flight

The Landing Data report for the incident flight was requested by the crew via ACARS at 0824. This was about 14 minutes after takeoff, and followed the flight's receipt of KBUR ATIS H information at 0822. The Landing Data report was received at 0824. The report is included in attachment 4, SWA 278 ACARS Message Log. In the message log, the report is labelled “PWB Landing Response”. According to this log, the PWB System used an RCC of 5- GOOD for runway 08. This value is the same as appears in the KBUR weather sent to the flight via ACARS at 0822. The wind used in the Landing Data report calculations (278° at 5 knots) was the same as the 0753 METAR wind, converted to magnetic direction by subtracting the magnetic variation at KBUR of 12E.³¹ The 0753 METAR wind is the same wind (when converted to a magnetic value for use in ATIS broadcast) that was reported on ATIS information H.

³¹ According to section 3.2.7 of the AOM, the PWB System uses magnetic direction for wind when making OPS/HP FACTUAL REPORT

The landing report returned to the flight by the PWB system included an analysis of this wind value that the system had used in its calculations. The Landing Data report included a 5 knot tailwind value for a landing on runway 08. The PWB Landing Data report returned the requirement for the use of autobrakes by the crew, and a stopping margin, with autobrakes set at maximum (ABM), of 245 feet. There was no stopping margin shown for the other two possible autobrake settings of AB2 and AB3, indicated by four dashes (----) next to AB2 and AB3 on the Landing Data report. According to section 10.7.1 of the AOM, pilots were to set an autobrake setting associated with a positive stopping margin. This was the only criteria for a stopping margin found in the AOM or the FOM.

8.2.7 Pilot Flying (PF) /Pilot Monitoring (PM) Roles and Responsibilities

Section 3.2.1 of the SWA FOM addresses the duties and monitoring responsibilities of the PF and the PM. Among responsibilities of the PF, the manual lists “Aircraft flight path control-flying assigned courses, speeds, and altitudes”. Responsibilities for the PM include “Assisting the PF in developing the plan”, and “Monitoring, taxiing, flight path, airspeed, aircraft configuration, and navigation”. The manual further states “The PM informs the PF when a limitation may be exceeded (e.g. flap placard speeds) or any deviation from standard operating procedures or stated intentions is detected in addition to the required deviation callouts.” Required deviation callouts during an approach are listed in the manual in section 11.1.3, and include a callout by the PM of “airspeed” when the airspeed is outside the V_{TARGET} speed range, defined in the next section, and “glideslope” when glideslope displacement is +/- 1 dot.

8.2.8 Stabilized Approach Policy

The SWA FOM section 11.1.1 specifies the airline’s criteria for a stabilized approach.

Regarding airspeed, the manual states “By 1000 ft. above the touchdown zone, the aircraft must be in the V_{TARGET} speed range. V_{TARGET} speed range is $V_{TARGET} +10$ knots and -5 knots. The PF should clearly communicate adjustments for an updated wind report from tower.”

Regarding aircraft flight path, the policy states:

By 1000 ft. above the touchdown zone, the aircraft must be on appropriate glidepath with a normal descent rate. Maintain a stable approach path. Normal glidepath descent rate is 700-800 fpm³². Final approach segments with glidepaths greater than 3° and/or high groundspeeds may require a sustained descent rate in excess of 1,000 fpm. This is acceptable as long as this condition is briefed, and all other stabilized approach criteria are met.

performance calculations. METAR wind is given in relation to true north.

³² Feet per minute

The section states “Once established, stabilized approach criteria must be maintained throughout the rest of the approach.”, and “If stabilized approach criteria are not met, execute or direct a go-around/missed approach.” This section also states, “It is the duty and responsibility of any Flight Deck Crew Member to execute or direct a go-around/missed approach when the stabilized approach criteria are not met. Additionally, anytime the approach or landing appears unsafe, execute or direct a go-around/missed approach.” In an earlier paragraph of this section, the manual states “Momentary deviations of glidepath, course, airspeed, and sink rate do not require an immediate go-around. Make required deviation callouts.”

8.2.9 Approach Procedures and Go-Around/Missed Approach Criteria

Section 11.1.1 of the AOM, *Approach Procedures and Restrictions–All Approaches*, states “During the final approach phase, monitor wind condition information”.

Section 15.5.5 of the AOM, *Approach Precautions*, states “Do not continue the approach if known windshear exists”.

Section 11.8 of the AOM lists the circumstances when a go-around/missed approach must be executed. Among them and potentially relevant to this incident, are:

- *The approach does not meet stabilized approach criteria*
- *The pilot determines that a landing in the touchdown zone cannot be safely accomplished because of one or both of the following:*
 - *The required descent or maneuvering will exceed the stabilized approach criteria.*
 - *The aircraft touches down beyond 1500 ft. with an insufficient PWB System-computed stopping margin.*

9.0 FAA Guidance, Regulation, and Oversight

FAA Advisory Circular (AC) 25-32 has the subject *Landing Performance Data for Time-of-Arrival Landing Performance Assessments*. It provides guidance and standardized methods that airplane operators can use when developing landing performance data for time-of-arrival landing performance assessments. The AC notes that its guidance is neither mandatory nor regulatory and does not constitute a requirement for operators to perform time-of-arrival landing performance assessments. Additionally, the AC provides no guidance on updating the impact of changing environmental conditions, such as wind, once a time-of-arrival landing performance assessment has been made, nor any guidance as to when during a flight the initial assessment should be performed.

The AC recommends the following regarding wind to use in the time-of-arrival landing performance assessment:

Winds within the approved landing operating envelope (1) not more than 50 percent of the nominal wind components along the landing path opposite to the direction of landing; and (2) not less than 150 percent of the nominal wind components along the landing path in the direction of landing.

FAA SAFO (Safety Alert for Operators) 19001, dated 3/11/2019, has the subject *Landing Performance Assessment at Time-of Arrival*. The SAFO defines the term *at time-of-arrival* as "...a point in time close enough to the airport to allow the crew to obtain the most current meteorological and runway surface conditions considering pilot workload and traffic surveillance, but no later than the commencement of the approach procedures or visual approach pattern."³³ The SAFO discusses best practices for conducting a landing distance assessment at time-of-arrival. Regarding the time the assessment should be conducted, it states:

An assessment is initially performed when landing weather and field conditions are obtained, usually around Top of Descent (TOD). It is important to note the time of the latest Field Condition report and any associated reliable braking action reports. A number of overruns have occurred when pilots were provided with a runway condition that was no longer reliable given changes in meteorological conditions. Pilots are strongly advised to review the weather conditions and compare that to the time of the latest braking action report. The assessment should include consideration of how much deterioration in field conditions can be tolerated, the minimum RwyCC(s) and Field Condition (FICON) or Braking Actin Reports needed to safely land should these factors deteriorate from the ones used in the TOD landing distance.

FAA Order 8900.1 directs the activities of FAA aviation safety inspectors (ASI) responsible for the certification, technical administration, and surveillance of air carriers. It also provides direction for tasks related to aircraft accidents and incidents, investigations and compliance, the Aviation Safety Action Program (ASAP), administrative areas, and miscellaneous tasks not related to a specific regulation.

Volume 4, chapter 3, section 1, paragraph 4-503 of FAA Order 8900.1 is titled *Landing Distance Assessment at Time of Arrival*. This paragraph includes best practices for conducting landing distance assessment at time of arrival. Regarding timeliness of the assessment, the order states;

The assessment is initially performed when landing weather and field conditions are obtained, usually around Top of Descent (TOD). The assessment includes consideration of how much deterioration in field conditions can be tolerated so that a quick decision can be

³³ This SAFO had not been issued at the time of this incident. The document it superseded, SAFO 06012, dealt with the same subject and had a nearly identical definition of "time-of-arrival".

made just prior to landing if the preceding aircraft provides a Pilot Weather Report (PIREP) of worse-than-expected braking action.

As noted above, there is no regulatory requirement for an operator to perform a time-of-arrival landing performance assessment. Regarding meteorological conditions, 14 *CFR* 121.601(c) states, “During a flight, the aircraft dispatcher shall provide the pilot in command any additional available information of meteorological conditions (including adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear), and irregularities of facilities and services that may affect the safety of the flight.” This requirement is echoed in section 17.1.3 of the SWA FOM and section 14.1 of the SWA Dispatch Operations Manual.

14 *CFR* 121.603(b) states, “During a flight, the pilot in command shall obtain any additional available information of meteorological conditions and irregularities of facilities and services that may affect the safety of the flight.”

FAA oversight of SWA was conducted by the FAA SWA Certificate Management Office (CMO) in Irving, TX. Interviews were conducted with the SWA CMO Supervisory Principal Operations Inspector, the SWA Aircrew Program Manager, and the SWA CMO Dispatch Inspector. Transcripts of their interview are at attachment 3.

F. LIST OF ATTACHMENTS

Attachment 1 – Crew Interview Summaries
Attachment 2 – Company Interviews
Attachment 3 – FAA Interviews
Attachment 4 – Southwest Flight 278 ACARS Message Log
Attachment 5 – Southwest Flight 278 Dispatch Release
Attachment 6 – Southwest Flight 278 Weather Packet

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