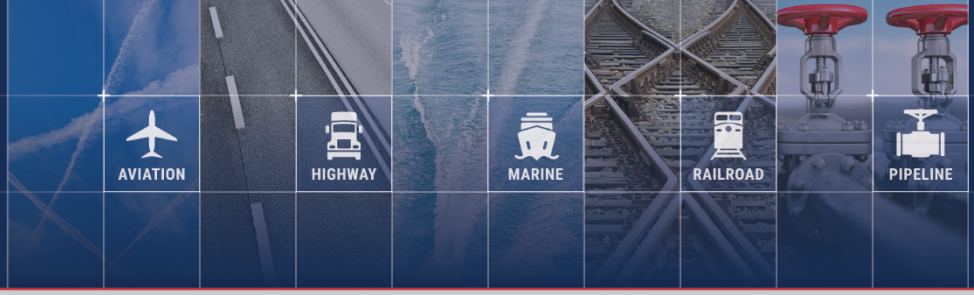

Aviation Investigation Final Report

Location:	Burbank, California	**Incident Number:**	DCA19IA036
Date & Time:	December 6, 2018, 09:02 Local	**Registration:**	N752SW
Aircraft:	Boeing 737	**Aircraft Damage:**	Minor
Defining Event:	Runway excursion	**Injuries:**	117 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

Southwest Airlines (SWA) flight 278 was en route to Bob Hope Airport (BUR), Burbank, California, when it overran the end of runway 8. The airplane came to rest about 144 ft past the departure end of runway and 71 ft into an engineered materials arresting system. Shortly before the airplane touched down on the runway, the tower controller informed the flight crew that heavy precipitation was occurring directly over the airport and that the wind was from 270° at 11 knots. BUR runway 8, which was 5,802 ft in length, was one of the shortest runways at airports where SWA operated.

Incident Sequence

Before the airplane reached the top of descent (about 0839), the flight crew requested and received a landing data report generated from the SWA performance weight and balance (PWB) system. The report indicated that maximum autobrakes should be used for landing on runway 8 and that the stopping margin—that is, the difference between the calculated landing distance (including a 15% safety factor) and the runway length available—would be 245 ft. The PWB system calculations assumed that touchdown would occur 1,500 ft from the runway threshold and that the wind would be from about 280° at 5 knots (the wind direction and speed at the time of the airport's 0753 weather observation converted from true north to magnetic north). Both flight crewmembers expressed concern about the stopping distance given the wet runway, the tailwind that would be present, and the runway length, and they discussed that the braking action upon touchdown would need to be "pretty abrupt." Also, even though the first officer stated, during a postincident interview, that BUR "always has a low number" for the stopping margin, the captain stated that he had not previously seen a stopping margin as low as the one for the incident flight.

While the airplane was descending through the terminal area, the controller advised the flight crew that the pilot of a King Air airplane reported a 15-knot loss of airspeed on final approach

to BUR and that a corporate jet had just conducted a go-around at BUR because of the wind. However, after the tower controller cleared the airplane to land, the controller advised the flight crew that a pilot of a Boeing 737 airplane had reported braking action as "good" 10 minutes earlier.

Shortly before landing, the tower controller reported that the wind was from 270° at 10 knots and then, less than 1 minute later, from 270° at 11 knots, The SWA *B737NG Aircraft Operating Manual* (AOM) stated that the tailwind limit for landing was 10 knots. After the second wind report, the first officer stated, "we got eleven knots. You want to call it good?" The captain replied, "yeah." During a postincident interview, the captain stated that both he and the first officer assumed that the tailwind component would be about 9 to 10 knots (presumably because the wind would not be directly behind the airplane given the wind direction and the orientation of the runway).

The SWA 737 AOM also stated that, for tailwind landings, the target speed should be the reference landing speed (V_{ref}) plus 5 knots. The PWB system determined that the V_{ref} for the flight would be 126 knots, so the target speed should have been 131 knots. However, the aircraft performance study for this incident determined that the airplane's airspeed over the runway threshold was 137 knots. Also, the true airspeed and groundspeed (based on flight data recorder data) showed that a tailwind of 13 to 18 knots was over the runway at that time and not the 5-knot tailwind that the PWB system calculations assumed.

Further, the aircraft performance study found that the airplane touched down about 2,500 ft past the runway threshold, which was 1,000 ft beyond the 1,500-ft touchdown point assumed in the PWB system calculations. This study finding was consistent with a BUR tower controller's observation of the airplane touching down near the intersection of taxiway D7 and runway 8, which was about 2,600 ft from the runway threshold.

The AOM stated that, if an airplane were to touch down beyond the 1,500-ft point, the stopping margin that the PWB system calculated would be "invalid" and that, in some cases, the runway length would be "insufficient" for the airplane to stop. In this case, the longer-than-normal touchdown point, the higher-than-expected tailwind, and the faster-than-nominal approach speed increased the airplane's required landing distance, making the 245-ft stopping margin calculation invalid.

The AOM also stated that, if the current weather conditions are significantly different than the anticipated conditions at the time of the PWB system calculations, higher-than-planned braking might be needed to account for the reduced or insufficient stopping margin. Flight data recorder data showed that the airplane's autobrakes were activated at touchdown but then disengaged almost immediately as a result of pilot-applied pressure to the brake pedals. The maximum left and right wheel brake pressure (indicating full manual braking) was reached about 6 seconds after touchdown and remained at maximum until 1 second before the airplane came to rest.

During a postincident interview, the captain stated that he was "blending in manual brakes" because the airplane was not slowing with maximum autobrakes. However, the captain's application of manual brakes almost immediately after touchdown was contrary to company

guidance, which stated that “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” and “once the landing roll is stabilized, transition to manual brakes…with adverse conditions, transition at a slower speed.” According to the aircraft performance study, the maximum braking performance available from the runway was achieved even without proper use of maximum autobrakes.

The airplane initially reached and maintained a deceleration rate between about 0.3 and 0.4 G, but the deceleration rate decreased to between 0.15 and 0.20 G after the airplane crossed over the left edge of the runway from a grooved to a smooth paved surface. (This maneuver is consistent with the captain’s statement about potentially turning onto taxiway D1 and his application of left rudder and the tiller.) The decrease in deceleration is consistent with a lower friction coefficient on the smooth paved surface compared with that on the grooved runway surface. Once the airplane entered the engineered materials arresting system, the deceleration rate increased to a maximum of about 0.6 G until the airplane stopped.

Flight Crew Performance

The flight crew had multiple opportunities to assess whether to continue the approach to a landing, but none of those opportunities resulted in a decision to go around. Although the flight crew received automatic terminal information service (ATIS) information Hotel before the airplane reached the top of descent, as required by SWA procedures, the crew failed to consider that the information might no longer be valid after receiving reports of changing weather conditions. Also, when the flight crew received the report from the tower controller indicating that the wind was from 270° at 10 knots, the crew recognized that the tailwind would be at SWA’s limit. Shortly afterward, the crew learned that the wind speed had increased to 11 knots. However, neither of these wind reports led to flight crew recognition that the PWB system-calculated stopping margin was no longer valid. Specifically, the crew did not discuss that the wind in the landing data report (which was issued about 37 minutes earlier) no longer reflected the current wind or that an updated landing data report from the PWB system was needed, thus missing another opportunity to better understand and address the deteriorating weather situation.

Both ATIS information Juliet and Kilo, which became effective about 21 and 9 minutes, respectively, before touchdown, included windshear advisories, and SWA procedures stated that pilots should not continue an approach if known windshear existed. Although the approach controller did not notify the incident flight crew about the more recent ATIS reports, which also discussed the significantly increased (11-knot) tailwind, the crew should have recognized the potential threat for windshear after receiving and acknowledging the reports of an airplane that had a 15-knot loss of airspeed on final approach and an airplane whose pilot conducted a go-around because of wind, and the crew should have discontinued the approach after receiving these reports.

During a postincident interview, the captain stated that pilots could request multiple landing data reports from the PWB system but that the same data might be received if the weather information in the system had not been updated. In this case, the weather information would have been updated because, after the BUR hourly observation at 0753 (which was the basis for

the original PWB landing data calculations), two additional weather reports (a special weather observation and an hourly weather observation) were generated at 0841 and 0853, respectively. (These reports became the basis for ATIS information Juliet and Kilo). In addition, the flight crew had the option to manually enter the wind information. With a 10- or an 11-knot tailwind (as reported in the 0841 and 0853 weather observations), updated PWB system calculations would likely have indicated that the airplane could not safely land on runway 8, especially given that the previously calculated stopping margin (when the tailwind was 5 knots) was only 245 ft.

The National Transportation Safety Board (NTSB) evaluated why the flight crew continued the approach to a landing. The captain reported that he had flown into BUR between 80 and 100 times. The captain also reported that his previous flights into BUR occurred in visual flight rules flight and without any significant precipitation. The first officer reported that he had flown into BUR at least 100 times and estimated that he encountered a tailwind or rain from 5% to 10% of time. Although the flight crewmembers had experience landing on the short runway, their lack of substantial exposure to adverse weather at the airport resulted in pilot mental models for landing that did not fully account for the environmental challenges that compounded the short runway challenges.

In addition, the flight crew's decision to continue the approach to a landing was consistent with a psychological concept referred to as plan continuation bias, which is an unconscious cognitive bias to continue with an original plan despite changing conditions. After hearing the wind report indicating an 11-knot tailwind, the flight crew justified continuing the approach, even though the tailwind component would be "right on the edge" of the company's 10-knot limit. (Specifically, the 270° wind was 10° off from a direct tailwind for runway 8; thus, the 11-knot wind speed would result in a tailwind between 10 and 11 knots.) The crewmembers did not consider taking another action, such as performing a go-around to allow them time to reassess the situation, which would have been consistent with company guidance that instructed pilots to go around if a landing appeared unsafe. Thus, the flight crew's decision to land on a short runway with the reported 11-knot wind almost directly on the airplane's tail was intentional due to plan continuation bias, and the decision was inappropriate.

Touchdown Location

The airplane touched down on the runway 1,000 ft beyond the 1,500-ft touchdown point assumed in the PWB system calculations and specified in SWA procedures. The horizontal distance from the runway threshold that was required for the airplane to descend and touch down was substantially increased by the airplane's higher-than-anticipated groundspeed. Contributing to the increased groundspeed were the higher-than-expected tailwind and the airplane's faster-than-nominal approach speed as it crossed the threshold. (The target speed was 131 knots, V_{ref} plus 5 knots. The airplane crossed the threshold at 137 knots, V_{ref} plus 11 knots.) Although the wind and the excess airspeed both contributed to the airplane's higher groundspeed (which led to the longer-than-normal touchdown), the wind played more of a role than the excess airspeed.

The captain estimated that the airplane touched down between 1,300 and 1,500 ft from the runway threshold. This estimate was based on the expected timing between 10 ft above ground

level (when the airplane began to flare) and touchdown and was not based on external cues, such as the painted runway markings and relevant taxiway intersections. Also, the first officer was "pretty confident" that the airplane touched down by 1,500 ft. However, the tailwind increased the groundspeed and thus the distance traveled in a given time, causing the airplane to touch down farther on the runway than both flight crewmembers assumed.

The NTSB recognizes that, according to their postincident interviews, both flight crewmembers did not realize that the airplane touched down 2,500 ft from the runway threshold. The captain's failure to correct the excess approach speed and both flight crewmembers' lack of awareness of the long touchdown were consistent with the crew experiencing a narrowing of attention. This phenomenon occurs when certain information is overlooked as individuals focus on a narrow field of attention perceived to be the most threatening or salient (in this case, the tailwind and the need for aggressive braking upon touchdown).

The NTSB considered whether the pavement change on the runway (the first 500 ft beyond the runway 8 threshold was constructed of light-colored concrete, and the remainder of the runway was constructed with dark-colored asphalt) created a visual illusion that affected the flight crew's assessment of where the airplane touched down. Because the captain stated that he was following guidance from the heads-up display and precision approach path indicator lights to the runway, the pavement change was likely not a factor in the crew's assessment of the touchdown point.

According to the AOM, a go-around should be performed if "the pilot determines that a landing in the touchdown zone cannot be safely accomplished because…the aircraft touches down beyond 1500 ft. with an insufficient PWB System-computed stopping margin." The AOM also stated that a landing on a runway with a reduced or an insufficient stopping margin "becomes more critical on shorter runways" (such as runway 8 at BUR) and that a go-around would be "the better option" compared with continuing the landing. The crewmembers' recognition that the airplane had flown beyond the touchdown point would have been another trigger to conduct a go-around and reassess the landing conditions. (SWA procedures allowed flight crews to go around until the thrust reverser levers were raised.)

As previously stated, the flight crew should have recognized that the landing data report that the PWB system calculated (which provided a relatively short stopping margin that concerned the flight crew) might no longer be accurate. Thus, even with the stressful, fast-paced, and dynamic situation that was occurring, the flight crew should have called for and executed a go-around.

Southwest Airlines Procedures

After the incident, SWA issued a flight operations bulletin that discussed that company pilots must execute a go-around if an airplane touches down beyond the first one-third of the available runway length, the first 3,000 ft of the available runway length, or 1,500 ft plus the planned PWB system-calculated stopping margin, whichever is the most restrictive. For the incident flight, the first and last criteria would have applied, with the last criterion being the most restrictive because it would have required a go-around for a touchdown occurring at or beyond 1,745 ft—about 760 ft before the touchdown point during the incident landing. (As

previously stated, at the time of the incident, SWA required a go-around if landing in the touchdown zone could not be safely accomplished because the airplane touched down beyond 1,500 ft with an insufficient PWB system-computed stopping margin.)

SWA also provided the NTSB with a list (dated June 2020) of other safety improvements that resulted from this incident. However, none of those safety improvements required company flight crews to reassess whether the information in a PWB landing data report remained valid in changing conditions. This incident demonstrated that landing conditions can change during a flight and that the landing data report that a flight crew receives before the top of descent might not be sufficient to ensure a safe stopping distance at the time of arrival. SWA procedures did not specify the conditions that would warrant obtaining updated landing data reports from the PWB system (such as when a controller-reported wind differs significantly from the wind used in a landing data report). In addition, SWA did not instruct its flight crews to verify the PWB system performance data as an airplane gets closer to its destination, which would take little time to accomplish.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

(1) The flight crewmembers' decision, due to plan continuation bias, to continue the approach despite indications of windshear and a higher-than-expected tailwind and (2) the flight crew's misperception of the airplane's touchdown point, which was farther down the runway than the crew assumed because of the faster-than-expected groundspeed. Contributing to the accident was Southwest Airlines' lack of guidance to prompt flight crews to reassess operator-provided landing data when arrival weather conditions differ from those used in the original landing data calculation.

Findings

Personnel issues	Incorrect action performance - Flight crew
Environmental issues	Tailwind - Decision related to condition
Organizational issues	Adequacy of documents/info - Operator
Personnel issues	Flight planning/navigation - Flight crew
Environmental issues	Rain - Decision related to condition
Organizational issues	(general) - Operator
Personnel issues	Knowledge of procedures - Flight crew

Factual Information

History of Flight

Landing	Runway excursion (Defining event)

On December 6, 2018, about 0903 Pacific standard time, Southwest Airlines (SWA) flight 278, a Boeing 737-7H4, N752SW, overran the end of runway 8 during the landing roll at Bob Hope Airport (BUR), Burbank, California, and came to rest in the engineered materials arresting system (EMAS) at the departure end of the runway. The 2 pilots, 3 flight attendants, and 112 passengers were not injured. The airplane sustained minor damage. The regularly scheduled domestic passenger flight was operating under the provisions of Title 14 *Code of Federal Regulations* (*CFR*) Part 121. Instrument flight conditions prevailed at the time of the incident, and an instrument flight rules flight plan was filed.

The flight departed from Metropolitan Oakland International Airport, Oakland, California, about 0810. The captain was the pilot flying, and the first officer was the pilot monitoring.

About 0822, the flight crew requested, via the aircraft communications addressing and reporting system (ACARS), the weather at BUR and received automatic terminal information service (ATIS) information Hotel, which was issued at 0753. The ATIS information indicated that the wind was from 280° at 5 knots, visibility was 1 1/4 miles in heavy rain and mist, and the ceiling was broken clouds at 1,100 ft above ground level (agl).

About 0824, the crew received, via ACARS, a landing data report generated from the company's performance weight and balance (PWB) system. The report was based on the reported wind from the most recent meteorological aerodrome report (290° at 5 knots) converted to bearing from magnetic north (278° at 5 knots), the airplane's estimated landing weight (120,800 pounds), the planned flap setting (40°), and the reported runway condition (good). (Note: The wind direction in meteorological aerodrome reports and similar products is relative to true north, and the wind direction provided by air traffic control [ATC] and in ATIS reports is relative to magnetic north. At BUR, magnetic north is 12° east of true north.) The report indicated that maximum autobrakes should be used for landing on runway 8 (which was 5,802 ft in length) and that the stopping margin (that is, the distance between the location where the airplane should come to a stop, plus a 15% safety factor, and the end of the runway) would be 245 ft. The stopping margin calculation assumed, among other things, a touchdown at 1,500 ft from the runway threshold. According to the cockpit voice recorder (CVR), the flight crewmembers were concerned about the stopping distance given the wet runway, the tailwind conditions, and the runway length. Also, the captain and first officer discussed that, because of the runway conditions, the braking would be "pretty abrupt."

At 0848:14, the CVR recorded a controller from the Los Angeles Air Route Traffic Control Center informing the flight crew about "moderate to heavy to extreme" precipitation between

the airplane's position at the time and BUR. The center controller transferred the flight to the next ATC facility, the Southern California Terminal Radar Approach Control; at 0851:27, the approach controller instructed the flight crew to descend the airplane to 8,000 ft and expect the "ILS [instrument landing system] Zulu" runway 8 approach to BUR. The first officer acknowledged the instructions and advised the controller that they had ATIS information Hotel. Upon reaching MIKEI, an initial approach fix for the approach, the controller cleared the flight crew to conduct the approach. Between 0854:37 and 0854:51, the controller advised the flight crew that, about 10 minutes earlier, the pilot of King Air airplane reported a 15-knot loss of airspeed on final approach to BUR and that a corporate jet had just conducted a go-around at BUR. About 2 minutes later, the controller informed the flight crew that the go-around occurred because of the wind. The first officer acknowledged this information.

According to the company's PWB system, the reference landing speed was 126 knots (indicated airspeed), and the target speed was 131 knots. Flight data recorder (FDR) data showed that, about 0858, the airplane turned onto its final heading and captured the glideslope and localizer for the ILS approach. About 1 minute later, the flight crew selected a flap setting of 40°, and the airplane's indicated airspeed was between 133 and 136 knots.

At 0858:54, the approach controller instructed the flight crew to contact the BUR ATC tower, and the first officer acknowledged this instruction and made initial contact with the tower at 0859:17. Between 0859:21 and 0859:36, the tower controller advised the flight crew about "moderate to heavy precipitation" between the flight's position at the time and the airport, stated that the wind was 260° at 9 knots, and cleared the airplane to land on runway 8. The controller also advised the flight crew that, 10 minutes earlier, the pilot of a Boeing 737 airplane reported braking action as "good." Less than 1 minute later, the controller further advised that heavy precipitation was directly over the airport. The first officer acknowledged each of the transmissions from the controller.

At 0900:43, the controller stated that the wind was from 270° at 10 knots. Five seconds later, the first officer stated to the captain that 10 knots "is the max," referring to the 10-knot tailwind limitation for landing in the SWA *B737NG Aircraft Operating Manual* (AOM); the captain also stated "max" and noted that the autopilot "has got a handle on it" thus far. At 0901:33, the captain asked that the windshield wipers be set to high. Three seconds later, the controller stated that the wind was from 270° at 11 knots. At 0901:52, the first officer stated, "we got eleven knots. You want to call it good?" The captain replied, "yeah." During postincident interviews, the captain stated that he and the first officer agreed that the tailwind component would be about 9 to 10 knots and thus within the limit, and the first officer described the 11-knot wind as being "right on the edge" of the tailwind limit.

During a postincident interview, the captain reported that, when the airplane was about 400 ft agl, the airplane exited the clouds, and he had a clear view of the runway. The captain also reported that, at the decision altitude of 1,007 ft mean sea level (about 280 ft agl), he disconnected the autothrottles and the autopilot and continued to descend using the precision approach path indicator lights as a descent path reference. (The CVR recorded the captain stating, "we need some kind of lights. I got some lights," about that time.) The captain further reported that, during the landing flare (when the airplane was about 5 ft agl), the rain intensity "picked up and visibility decreased a little bit."

The National Transportation Safety Board's aircraft performance study for this incident found that the airplane crossed the runway threshold at an altitude of 54 ft agl and an indicated airspeed of 137 knots. (The ILS runway 8 approach procedure noted a threshold crossing height of 60 ft when following the 3° glideslope.) The captain reported (during a postincident interview) that he was aware of the 1,000-ft markers as the airplane crossed the runway threshold. FDR data showed that the airplane touched down at 0902:35 at an indicated airspeed of 126 knots and a groundspeed of 151 knots.

During postincident interviews, the captain estimated that the airplane touched down between 1,300 and 1,500 ft from the runway threshold based on the timing from about 10 ft agl to touchdown (and not runway markings). The first officer stated that the airplane touched down within the touchdown zone, which he defined as 1,000 to 1,500 ft from the threshold, and was "pretty confident" that the airplane touched down by 1,500 ft. The aircraft performance study found that the airplane touched down 2,504 ft from the runway threshold. A controller in the BUR tower observed the airplane touch down near the taxiway D7 intersection with runway 8, which was about 2,600 ft from the runway threshold. This observation was consistent with the related finding from the aircraft performance study.

According to the FDR, the airplane's autobrakes, auto speedbrakes, and ground spoilers were activated at touchdown. Both thrust reversers were fully deployed within 3 seconds of touchdown. Brake pressure reached its maximum of 3,000 psi in about 6 seconds. At 0902:45, the CVR recorded the first officer stating, "come on baby," which was followed by the captain stating "whoa-ah" and then expletives. The CVR recorded sounds of impact at 0902:56.

The captain stated that, after touchdown, he used maximum reverse thrust and that he heard and felt the brakes "chattering." He verified that the speedbrake handle was extended and started "blending in manual brakes after that" because the airplane was not slowing with reverse thrust and maximum autobrakes. The captain became concerned about the airplane stopping as it passed runway 15/33 (which intersected with runway 8 about 3,765 ft from the runway 8 threshold). The captain noted that, with 1,000 to 500 ft remaining on the runway, the airplane stopped decelerating. The captain thought that he might be able to make a turn onto taxiway D1 (which intersected runway 8 about 5,340 ft from the runway threshold), but, as he tried to turn using left rudder and the tiller, the airplane did not respond. The captain reported that the nosewheel was skidding and that he straightened it so that the airplane would enter the EMAS without the nosewheel turned sideways.

FDR data showed that, during the first 17 seconds after touchdown (between 0902:35 and 0902:52), the airplane reached and maintained a deceleration rate between about 0.3 and 0.4 G, and the airplane's groundspeed decreased from 151 to 50 knots. During the next 5 seconds, the deceleration rate decreased to between 0.15 and 0.20 G as the airplane crossed over the left edge of the grooved runway onto smooth pavement, and the groundspeed slowed to about 24 knots at 0902:57. The deceleration rate then increased to a maximum of about 0.6 G from the time that the airplane entered the EMAS to the time that the airplane came to a stop. The airplane came to rest about 71 ft into the EMAS, 144 ft past the end of runway 8, and 107 ft to the left of the runway centerline. The crewmembers and passengers evacuated the airplane via airstairs.

Pilot Information

Certificate:	Airline transport	**Age:**	58,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	Helicopter	**Restraint Used:**	5-point
Instrument Rating(s):	Airplane; Helicopter	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	August 22, 2018
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	February 23, 2018
Flight Time:	15410 hours (Total, all aircraft), 11350 hours (Total, this make and model), 4995 hours (Pilot In Command, all aircraft), 247 hours (Last 90 days, all aircraft), 90 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport	**Age:**	53,Male
Airplane Rating(s):	Single-engine land; Multi-engine sea	**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	5-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine	**Toxicology Performed:**	
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	October 21, 2018
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	September 30, 2018
Flight Time:	10855 hours (Total, all aircraft), 5000 hours (Total, this make and model), 4400 hours (Pilot In Command, all aircraft), 208 hours (Last 90 days, all aircraft), 28 hours (Last 30 days, all aircraft), 1 hours (Last 24 hours, all aircraft)		

The captain reported that he flew into BUR typically every month and estimated that he had landed there between 80 and 100 times. The first officer reported that he had flown into BUR at least 100 times.

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	**Registration:**	N752SW
Model/Series:	737 7H4	**Aircraft Category:**	Airplane
Year of Manufacture:	1999	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	29804
Landing Gear Type:	Retractable - Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	154500 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	Cfm Intl.
ELT:		**Engine Model/Series:**	CFM56 SERIES
Registered Owner:	Southwest Airlines Co	**Rated Power:**	
Operator:	Southwest Airlines	**Operating Certificate(s) Held:**	Flag carrier (121)

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	BUR,778 ft msl	**Distance from Accident Site:**	0 Nautical Miles
Observation Time:	08:53 Local	**Direction from Accident Site:**	0°
Lowest Cloud Condition:	Few / 400 ft AGL	**Visibility**	1.5 miles
Lowest Ceiling:	Overcast / 1300 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	11 knots /	**Turbulence Type Forecast/Actual:**	None / None
Wind Direction:	280°	**Turbulence Severity Forecast/Actual:**	N/A / N/A
Altimeter Setting:	29.91 inches Hg	**Temperature/Dew Point:**	8°C / 8°C
Precipitation and Obscuration:	Heavy - Showers - Rain		
Departure Point:	Oakland, CA (OAK)	**Type of Flight Plan Filed:**	IFR
Destination:	Burbank, CA (BUR)	**Type of Clearance:**	IFR
Departure Time:	08:10 Local	**Type of Airspace:**	

BUR had an automated surface observing system (ASOS) that was augmented by ATC personnel. The ASOS is the official weather reporting source at the airport. ATIS and ATC

reports provide ASOS wind information that has been converted from true north to magnetic north for runway orientation.

The 0853 meteorological aerodrome report (about 10 minutes before the incident) is shown in the data field above. The 5-minute observation at 0905 (about the time of the incident) reported that the wind was from 280° at 13 knots, visibility was 1 1/4 miles in heavy rain and mist, and the hourly precipitation since the 0853 observation was 0.13 inch. The average 2-minute wind reported by the ASOS at 0905 was from 279° at 13 knots with the peak gust at 18 knots in heavy rain. The special weather observation that was issued at 0915 (about 12 minutes after the incident) stated that the wind was from 290° at 8 knots, visibility was 1 mile in heavy rain and mist, and the hourly precipitation since the 0853 observation was 0.26 inch.

The captain reported that he had not previously encountered conditions such as those on the day of the incident; his previous flights into BUR occurred in visual flight rules flight and without any significant precipitation, although he had occasionally landed with a tailwind on runway 8. The first officer reported that he did not usually encounter weather at BUR that was similar to that during the incident flight. The first officer also reported that he had previously landed at BUR with "a bit of a tailwind" and with rain. The first officer estimated that he encountered tailwind or rain conditions during 5% to 10% of the landings there.

Airport Information

Airport:	Bob Hope Airport BUR	**Runway Surface Type:**	Asphalt;Concrete
Airport Elevation:	778 ft msl	**Runway Surface Condition:**	Wet
Runway Used:	08	**IFR Approach:**	ILS
Runway Length/Width:	5800 ft / 150 ft	**VFR Approach/Landing:**	Full stop

The first 500 ft of runway 8 (beyond the runway 8 threshold) was constructed of concrete. The rest of the runway was constructed of asphalt.

An EMAS was located at the departure end of runway 8. An EMAS is a Federal Aviation Administration-approved aircraft arresting system that consists of a bed of cellular concrete material blocks with a strength appropriate for the types of aircraft expected to use the airport. The blocks crush under the weight of an aircraft and bring it to a controlled stop within a short distance.

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	112 None	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	117 None	**Latitude, Longitude:**	34.200553,-118.35861

According to SWA, the following components sustained minor damage as a result of this incident: both engines, both engine inboard c-ducts, the air conditioning heat exchangers, the left engine inlet cowl, the left engine inboard fan cowl, three pitot probes, two angle-of-attack probes, and a total air temperature probe.

Medical and Pathological Information

After the incident, the captain and the first officer were tested for drugs and alcohol in accordance with 14 *CFR* Part 120, Drug and Alcohol Testing Program. The test results were negative.

Tests and Research

The aircraft performance study for this incident found that the airplane's indicated airspeed over the runway 8 threshold was 137 knots—the reference landing speed (V_{ref}) of 126 knots (as calculated by the PWB system) plus 11 knots. As stated in the Organizational and Management Information section, the target speed for tailwind landings was V_{ref} plus 5 knots; thus, the airplane's 137-knot airspeed over the runway threshold was 6 knots above the target airspeed for the incident landing (and the target airspeed calculation provided by the PWB system for the flight).

The airplane touched down about 10 seconds later at an indicated airspeed of 126 knots (V_{ref}). The touchdown point was 2,504 ft past the runway threshold, as determined from FDR latitude, longitude, and weight-on-wheels data. (The result was also consistent with the sound similar to landing gear touchdown that the CVR recorded at 0902:35.) The touchdown point

was about 1,000 ft beyond the nominal 1,500-ft touchdown point assumed in the PWB system calculation.

According to the true airspeed and the groundspeed computed from FDR data, a tailwind of 13 to 18 knots—not the 5-knot tailwind assumed in the PWB system calculation—was over the runway during the ground roll. When the airplane crossed the runway 8 threshold, the true airspeed was 140 knots, and the groundspeed was 156 knots, corresponding to a 16-knot tailwind. When the airplane touched down, the true airspeed was 133.5 knots, and the groundspeed was 151 knots, corresponding to a 17.5-knot tailwind. The study noted that the calculated tailwind was consistent with the wind recorded by the ASOS on the field but that the tailwind that ATC reported to the crew during the flight ranged between 5 and 11 knots.

The ground roll distance that the PWB system calculated was 3,145 ft. Runway 8 was 5,802 ft in length, so the touchdown point that would have resulted in the airplane stopping with no runway remaining was 2,657 ft from the threshold. Even though the airplane touched down about 150 ft before that point, the higher airspeed and greater tailwind than those assumed in the PWB system calculations prevented the airplane from stopping within the system-computed 3,145-ft ground roll distance.

The study concluded that the higher-than-expected tailwind, the longer-than-normal touchdown point, and the faster-than-nominal approach speed all contributed to the overrun, with the long touchdown point being the most significant contributor. The study found that the airplane could have stopped on the runway with the faster-than-nominal approach speed and the tailwind even if the touchdown point had been up to 312 ft longer than the normal touchdown point of 1,500 ft from the runway threshold. Because the touchdown point was 2,504 ft from the threshold, either the tailwind or the faster approach speed by itself would have prevented the airplane from stopping before the end of the runway.

The study also examined the airplane's braking performance on the runway. The study found that the right wheel brake pressure was steady near 0 psi until 0902:34 and then increased to about 600 psi at 0902:35, 800 psi at 0902:39, and 3,000 psi (corresponding to full manual braking) at 0902:41, where the brake pressure remained until 0902:58 (1 second before the airplane came to rest). The left wheel brake pressure was steady near 400 psi until 0902:36 and increased steadily, reaching and maintaining 3,000 psi about the same time as the right brake pressure.

In addition, the study found that the FDR "autobrake applied" parameter changed from zero to one at 0902:35.6 and then changed back to zero at 0902:36.6, indicating that the autobrake system engaged after touchdown but then disengaged almost immediately as a result of pilot-applied pressure to the brake pedals. The study concluded that the maximum braking performance available from the runway was achieved despite the 6-second duration between the time of touchdown and the time that the left and right brakes reached their maximum brake pressure.

Performance Weight and Balance System

SWA implemented its PWB system in two phases. The first phase, which involved the PWB landing module (for use in calculating landing data), began in late 2016. Full use of the system began in 2017.

According to the AOM, the performance weight and balance 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, including PWB data centers, which provide real-time calculations that flight crews use to obtain, via ACARS, time-of-arrival landing performance information. The PWB system also produces landing data reports for flight crews to use during a flight to prepare for landing. Such reports provide crews with the information necessary to determine the suitability of the planned landing runway based on various factors, including the speeds for the approach and landing and the stopping margin for the selected runway. A safety factor of 15% is added to the PWB system-calculated distance for the airplane to come to a stop. The stopping margin is the difference between the calculated landing distance (including the 15% safety factor) and the runway length available. Although the PWB system will automatically use the wind information from the current meteorological aerodrome report when flight crews request landing data from the system, crews have the option to manually enter the wind information.

During a postincident interview, the captain stated that he requests an updated data report from the PWB system if the runway condition changes from dry to wet or the intended landing runway changes. The captain also stated that flight crewmembers can request multiple landing data reports from the PWB system but noted that, in the case of a wind change, crewmembers might receive the same information if the weather information that the PWB system uses has not been updated. In addition, the captain stated that he had not previously received a stopping margin from the PWB system that was as low as the one (245 ft) for the incident flight. The first officer stated that BUR "always has a low [PWB system] number for stopping margin," which he considered to be a concerning but not a significant issue.

In-flight Weather Information

The SWA *Flight Operations Manual* stated that the pilot monitoring (the first officer for this flight) should obtain ATIS information before reaching the top of descent. The dispatch release for this flight showed that the top of descent would occur about 21 minutes before landing. The FDR showed that the airplane began its descent from cruise altitude about 0839, which was 17 minutes after the flight crew had received ATIS information Hotel and about 23 minutes before landing.

According to SWA, the following ATIS reports were also in effect during the incident flight:

- ATIS information India, which became effective at 0841;
- ATIS information Juliet, which also became effective at 0841 and contained the same information as the previous ATIS along with a windshear advisory; and
- ATIS information Kilo, which became effective at 0853 and included a windshear advisory.

The ATC transcript for this incident showed that, about 0856, another SWA flight checked in with the Southern California Terminal Radar Approach Control while inbound to BUR, and the controller advised that flight crew that ATIS information Juliet had just become current. The incident flight crewmembers were on the same frequency at the time, but the available evidence did not indicate whether they heard this transmission. (The CVR transcript did not reflect the transmission.) The CVR transcript showed that the controller did not notify the incident flight crew when ATIS information Juliet and Kilo had become effective. During postincident interviews, both the incident captain and first officer stated that they were aware of the last wind report from the controller (270° at 11 knots), which they received about 1 minute before touchdown.

Approach Speed Information

According to the AOM, the PWB system defines the target speed as V_{ref} plus one-half the headwind component plus the full gust component and sets a minimum value of V_{ref} + 5 knots. A note in this part of the manual states that, for tailwind landings, the target speed should be V_{ref} + 5 knots. Another note states, "the purpose of the +5 knots is to ensure that V_2 [the takeoff safety speed] is met in case of a go-around. Under adverse conditions, the Captain may elect to fly at V_{REF}."

Normal Landing Procedures

The AOM instructed the pilot flying to "touch down between 1,000 and 1,500 ft from the landing threshold on centerline" and stated the following:

> *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.*
>
> *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…the PWB System-computed stopping margin may be invalid…[and] 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.*

Use of Autobrakes

The AOM stated that autobrake use was required if the landing data report from the PWB system specified that they be used (which was the case for the incident flight). The AOM also provided the following guidance regarding the transition from autobrakes to manual braking:

> *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* [pilot flying] *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.*

Go-Around/Missed Approach Requirements

According to the AOM, the pilot flying must execute a go-around/missed approach when, among other reasons, "the pilot determines that a landing in the touchdown zone cannot be safely accomplished because…the aircraft touches down beyond 1500 ft. with an insufficient PWB System-computed stopping margin." The AOM also advised pilots to monitor wind information during the final approach phase and not to continue the approach if known windshear exists.

The SWA *Flight Operations Manual* instructed pilots to "maintain a stable approach path" and "if stabilized approach criteria are not met, execute or direct a go-around/missed approach." The manual also stated that "momentary deviations of glidepath, course, airspeed, and sink rate do not require an immediate go-around." In addition, the manual stated, "anytime the approach or landing appears unsafe, execute or direct a go-around/missed approach."

Additional Information

SWA took several actions as a result of this incident. On May 6, 2019, SWA issued a flight safety alert for BUR regarding the runway 8 touchdown point. The safety alert stated the following:

> *RWY 08 is one of the shortest runways (5,802') in our system. For valid PWB stopping margins, ensure that touchdown occurs within the first 1,500' of the runway. If touchdown occurs beyond the 1,500' mark, the ability to stop on the remaining runway may be compromised and a go-around is the better option.*

The safety alert also stated the following:

> *The color contrast between the concrete and asphalt (approx. first 500' of RWY 8) may cause a visual illusion, which could affect your touchdown aim point. In addition to the painted runway markings, another visual reference to ensure a timely touchdown is to use TWY* [taxiway] *D8/TWY C8, which is approximately 1,400' past the threshold of RWY 08.*

On November 27, 2019, SWA issued a flight operations bulletin that discussed that a go-around would be required if an airplane touched down beyond 1,500 ft with an insufficient PWB system-computed stopping margin. The bulletin defined "touchdown zone" as "the area of the runway 500 ft to 3,000 ft beyond the landing threshold not to exceed the first one-third of the runway"; according to the bulletin, this definition aligned with regulatory and manufacturer guidance.

The bulletin stated that the definition for touchdown zone should not be confused with AOM guidance regarding the planned touchdown point of 1,000 to 1,500 ft from the runway threshold (consistent with the AOM version that was current at the time of the incident). Further, the bulletin stated the following:

> *A go-around must be executed if the aircraft touches down beyond the most restrictive of the following distances:*
>
> - *First one-third of the available runway length.*
> - *First 3,000 ft of the available runway length.*
> - *1,500 ft plus the planned PWB System-computed stopping margin.*

In addition, on June 17, 2020, SWA reported that it took actions, including the following, to mitigate the current and potential risks identified after the incident:

- Incorporated the above-referenced flight operations bulletin into the *Flight Operations Manual* revision that became effective in March 2020.

- Emphasized aeronautical decision-making under rapidly changing conditions in its 2019 distance learning.

- Asked company check airman to add runway landing distances and runway remaining distances to line checks.

- Included, in the 2020 pilot continuing qualification training, ground school discussions about plan continuation bias and rapidly changing conditions and emphasized, in maneuvers observation briefings, runway markings and PWB-computed stopping margins.

- Incorporated enhanced landing exercises into the 2020 line-oriented evaluation briefing to provide a better understanding of (1) the definition of the touchdown

zone, including how it relates to landing or go-around decision-making; (2) the difference between the planned touchdown point and the touchdown zone; (3) the relationship of PWB data to the touchdown point, landing distance required, stopping margin, and distance remaining; and (4) the effect that "less than optimum control" of variables such as airspeed, glidepath, and landing flare can have on landing distances and runway remaining distances.

Administrative Information

Investigator In Charge (IIC):	Lovell, John
Additional Participating Persons:	Eric West; FAA; Washington DC, DC Erin Carroll; Southwest Airlines; Dallas, TX Matthew Cain; SWAPA Safety
Original Publish Date:	July 20, 2022
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=98737