Aviation Investigation Final Report

Location:	Jacksonville, Florida	**Accident Number:**	DCA19MA143
Date & Time:	May 3, 2019, 21:42 Local	**Registration:**	N732MA
Aircraft:	Boeing 737	**Aircraft Damage:**	Substantial
Defining Event:	Runway excursion	**Injuries:**	1 Minor, 142 None
Flight Conducted Under:	Part 121: Air carrier - Non-scheduled		

Analysis

According to both pilots, the takeoff, climb, and cruise portions of the flight were uneventful. The No. 1 (left) thrust reverser was not operational and deferred for the flight in accordance with the airplane's minimum equipment list. The captain was the pilot flying for the accident flight, and the first officer was the pilot monitoring. The captain was also performing check airman duties for the first officer who was in the process of completing operating experience training.

During the approach to Jacksonville Naval Air Station (NIP), the flight crew had two runway change discussions with air traffic controllers due to reported weather conditions (moderate to heavy precipitation) near the field; the pilots ultimately executed the area navigation GPS approach to runway 10, which was ungrooved and had a displaced threshold 997 ft from the threshold, leaving an available landing distance of 8,006 ft.

As the airplane descended through 1,390 ft mean sea level (msl), the pilots configured it for landing with the flaps set at 30° and the landing gear extended; however, the speedbrake handle was not placed in the armed position as specified in the Landing checklist. At an altitude of about 1,100 ft msl and 2.8 nm from the runway, the airplane was slightly above the glidepath, and its airspeed was on target. Over the next minute, the indicated airspeed increased to 170 knots (17 knots above the target approach speed), and groundspeed reached 180 knots, including an estimated 7-knot tailwind.

At an altitude of about 680 ft msl and 1.6 nm from the threshold, the airplane deviated further above the 3° glidepath such that the precision approach path indicator (PAPI) lights would have appeared to the flight crew as four white lights and would retain that appearance throughout the rest of the approach. Eight seconds before touchdown, multiple enhanced ground proximity warning system alerts announced "sink rate" as the airplane's descent rate peaked at 1,580 fpm. The airplane crossed the displaced threshold 120 ft above the runway (the

PAPI glidepath crosses the displaced threshold about 54 ft above the runway) and 17 knots above the target approach speed, with a groundspeed of 180 knots and a rate of descent about 1,450 ft per minute (fpm). The airplane touched down about 1,580 ft beyond the displaced threshold, which was 80 ft beyond the designated touchdown zone as specified in the operator's standard operating procedures (SOP).

After touchdown, the captain deployed the No. 2 engine thrust reverser and began braking; he later reported, however, that he did not feel the aircraft decelerate and increased the brake pressure. The speedbrakes deployed about 4 seconds after touchdown, most likely triggered by the movement of the right throttle into the idle reverse thrust detent after main gear tire spin-up. The automatic deployment of the speedbrakes was likely delayed by about 3 seconds compared to the automatic deployment that could have been obtained by arming the speedbrakes before landing. The airplane crossed the end of the runway about 55 ft right of the centerline and impacted a seawall 90 ft to the right of the centerline, 9,170 ft beyond the displaced threshold, and 1,164 ft beyond the departure end of runway 10. After the airplane came to rest in St. Johns River, the flight crew began an emergency evacuation.

The tailwind, the airplane's excessive approach speed, and delayed speedbrake deployment increased the energy with which the airplane departed the runway and impacted the seawall, which contributed to the severity of the accident. However, postaccident landing performance calculations revealed that even if the airplane had landed on target speed within the operator's specified touchdown zone, it would not have been able to stop before reaching the end of the paved runway surface due to the presence of standing water (with depths close to that defined as a flooded condition) on portions of the runway and the resulting viscous hydroplaning. Viscous hydroplaning is associated with the buildup of water pressure under the tire due to viscosity in a thin film of water between a portion of the tire footprint and the runway surface.

The maximum wheel braking friction coefficient developed by the airplane during the landing ground roll was significantly less than the maximum wheel braking friction coefficient underlying the wet runway landing distances published in the airplane manufacturer's flight crew operating manual (FCOM), computed by the operator's onboard performance tool (OPT) application, and described in standards and models concerning landing performance in wet runway conditions. Conversely, had the airplane achieved the good braking action associated with a wet (but not flooded) runway published in the FCOM, it would have stopped on the runway even with the approach speed recorded before the accident landing, a 10-knot tailwind, and delayed speedbrake deployment.

The operator's guidance did not require flight crews to conduct en route landing performance calculations (landing distance assessment) under certain conditions, including reported braking action that is good or better, the use of maximum manual braking, and a tailwind of 5 knots or less. However, none of these criteria applied to the accident flight's approach to NIP. No braking action reports were provided to or requested by the accident flight crew, the flight crew briefed using autobrakes rather than maximum manual braking, and the last wind report provided to the flight crew (240° heading at 10 knots) suggested that an estimated 7-knot tailwind component existed during the landing on runway 10.

These considerations should have prompted the flight crew to perform updated landing performance calculations. However, had they done so, they still would have likely determined that the landing distance available on runway 10 was sufficient, under the conditions at the time, if they assumed good braking action (in the absence of reports indicating otherwise) and a merely wet (rather than flooded) runway condition.

To address braking friction shortfalls observed during landings on wet runways, Safety Alert for Operators (SAFO) 15009 (current at the time of the accident) suggested that operators take appropriate action to address landing performance on wet runways such as “assuming a braking action of medium or fair when computing time-of-arrival landing performance or increasing the factor applied to the wet runway time-of-arrival landing performance data.” However, similar guidance was not included in the operator’s SOPs at the time of the accident. Had such guidance been included, the flight crew would have been obligated to assign a surface condition value indicating a condition worse than “good” because the runway was wet, which would have prohibited them from attempting the landing with the tailwind.

To further clarify that advisory data for wet runway landings may not provide a safe stopping margin, especially in conditions of moderate or heavy rain on smooth runways, the Federal Aviation Administration issued SAFO 19003, which replaced SAFO 15009, 2 months after the accident. The new SAFO recommends that pilots verify, before initiating an approach, that the aircraft can stop within the landing distance available using a runway condition of medium-to-poor whenever there is the likelihood of moderate or greater rain on a smooth runway or heavy rain on a grooved/porous friction course runway.

The operator’s SOPs would have prohibited landing if runway 10’s surface condition were assigned a value less than “good,” given the existing tailwind at the time of the accident; according to the operator’s SOPs, a “wet” runway is considered to have good braking action. Consequently, the flight crew’s ability to determine whether they could safely land on the runway was critically dependent on their ability to determine that the actual condition of the runway was worse than “good.”

Notably, although not directly causal to the accident (because the worse-than-expected runway friction prevented the airplane from stopping on the runway), the airplane’s approach to NIP did not meet the operator’s stabilized approach criteria by the time the airplane descended to 1,000 ft agl, and several cues should have led the flight crew to call for a missed approach as required by SOPs. The airplane’s airspeed exceeded the target approach speed, it was above the glidepath, and its descent rate was greater than 1,000 fpm, which prompted multiple sink rate alerts that should have induced the flight crew to call for a missed approach. Additionally, the Miami Air Flight Operations Manual (FOM) required a flight crew to initiate a missed approach if the aircraft was not stabilized by 1,000 ft.

At the time of the accident, the first officer had only 18 hours in the Boeing 737 and most of his previous experience was operating light aircraft. Thus, his lack of experience flying jet aircraft likely played a role in his inadequate monitoring of the approach (his lack of experience was also exemplified by his failure to note, as part of his monitoring duties, that the speedbrake handle had not been armed after calling the item as part of the Landing checklist).

The captain’s continuation of the approach, contrary to the operator’s stabilized approach criteria, was likely due to a combination of factors. The first was plan continuation bias (an unconscious cognitive bias to continue with the original plan despite changing conditions). The captain's bias may have been reinforced by a self-induced pressure to land because the flight was late due to an earlier maintenance delay and, the captain and the first officer were approaching the end of their legal duty day. A go-around or diversion to an alternate airport would have caused additional delays.

Another factor was the captain's increased workload during the approach. Flying and monitoring duties are typically divided to reduce workload for each crewmember. However, cockpit voice recorder data indicate that, rather than relay queries or responses to ATC through the first officer, the captain made multiple radio communications to the approach controller regarding the weather, despite the first officer being responsible for performing this task as part of his monitoring duties.

In addition to performing some of the first officer's radio duties, the captain was also performing check airman duties in a bad weather situation. Further, the captain's failure to check that the speedbrake handle was armed, as part of the Landing checklist, was an oversight that was likely another result of his increased workload. Combined with plan continuation bias, the captain's increased workload from performing additional tasks narrowed his attention and limited his ability to recognize and correctly respond to the cues of an unstabilized approach.

Probable Cause and Findings

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

An extreme loss of braking friction due to heavy rain and the water depth on the ungrooved runway, which resulted in viscous hydroplaning. Contributing to the accident was the operator's inadequate guidance for evaluating runway braking conditions and conducting en route landing distance assessments. Contributing to the continuation of an unstabilized approach were 1) the captain's plan continuation bias and increased workload due to the weather and performing check airman duties and 2) the first officer's lack of experience.

Findings

Aircraft	Descent/approach/glide path - Not attained/maintained
Aircraft	Descent rate - Not attained/maintained
Aircraft	Airspeed - Not attained/maintained
Aircraft	Braking capability - Capability exceeded
Environmental issues	Wet surface - Effect on equipment
Environmental issues	Rain - Effect on equipment
Organizational issues	Adequacy of policy/proc - Not specified
Personnel issues	Cognitive overload - Pilot
Personnel issues	Forgotten action/omission - Flight crew
Personnel issues	Total experience w/ equipment - Copilot

Factual Information

History of Flight

Landing-landing roll	Other weather encounter
Landing-landing roll	Runway excursion (Defining event)
Landing-landing roll	Landing area overshoot

On May 3, 2019, at 2142 eastern daylight time, Miami Air International flight 293, a Boeing 737-81Q, N732MA, departed the end of runway 10 while landing at Jacksonville Naval Air Station (NIP), Jacksonville, Florida, and came to rest in shallow water in St. Johns River. Of the 2 pilots, 4 flight attendants, 1 mechanic (in the jumpseat), and 136 passengers onboard, one minor injury was reported; the rest were not injured. The airplane was substantially damaged. The flight was operated as a Title 14 *Code of Federal Regulations* Part 121 supplemental nonscheduled passenger flight from Leeward Point Field (MUGM), Guantanamo Bay, Cuba, to NIP. Marginal visual flight rules conditions prevailed at the time of the accident.

According to the flight crew, the day of the accident was the second day of a 3-day pairing; three flight legs were scheduled for the day; however, the schedule was amended before the accident flight to remove the originally scheduled third (last) leg of the day due to earlier maintenance delays. The pairing was the first time the pilots had flown together. The captain was the pilot flying (PF) for the accident flight, and the first officer was the pilot monitoring (PM). The captain was also performing check airman duties for the first officer who was in the process of completing operating experience training.

Before departing MUGM, the flight crew reviewed the dispatch paperwork and weather and noted that thunderstorms were in the forecast for their scheduled time of arrival at NIP; Orlando International Airport, Orlando, Florida, was listed as the alternate airport. The No. 1 (left) thrust reverser was not operational and deferred for the flight in accordance with the airplane's minimum equipment list (MEL). According to both pilots, the takeoff, climb, and cruise portions of the flight were uneventful.

During postaccident interviews, the flight crew stated that, about 30 minutes before landing at NIP, the flight deviated around weather as it approached the Jacksonville area. According to the captain, the weather was "nothing serious." Available weather data near this time indicated rain showers or thunderstorm growth over NIP from 2110 onward. Based on the weather forecast information provided in the flight plan, which indicated variable wind at 20 knots with 30-knot gusts, thunderstorms, and rain, the flight crew set up the area navigation (RNAV) GPS approach to runway 10 in the flight management system and briefed setting the autobrake at level 2.

According to data from the cockpit voice recorder (CVR), about 2122, the first officer checked in with the Jacksonville International Airport (JAX) airport traffic control tower radar approach (RP) controller indicating the flight's altitude at 13,000 ft mean sea level (msl). The RP controller acknowledged and advised the flight to expect the RNAV approach to runway 28 at NIP, which the first officer acknowledged. About 10 seconds later, the JAX RP controller advised the flight crew of moderate-to-heavy precipitation on the final approach to runway 28. The captain acknowledged and asked about the wind conditions and indicated that he could not pick up the NIP automatic terminal information service (ATIS) (see Airport Information).

After checking with NIP airport traffic control tower controllers, the RP controller advised the flight crew that the wind was from 350° at 4 knots. The captain then asked if weather conditions looked better for runway 10. The RP controller responded that, for runway 10, conditions showed moderate-to-heavy precipitation beginning about 5 miles out on the final approach. The captain replied that the flight would continue the approach to runway 28. The RP controller advised the flight crew to descend and maintain at 5,000 ft msl, which the first officer acknowledged.

At 2125:45, the RP controller provided additional weather information to the flight crew, stating that moderate-to-heavy precipitation was present east and west of the airport; he asked the flight crew if they wanted to stay with the RNAV approach for runway 28. The captain replied, "ah yes sir, what- whichever looks better an ah then when I get closer I check how it is." The RP controller assigned the flight crew heading 010 and instructed the pilots to descend to 3,000 ft msl. The flight crew acknowledged and entered the RNAV approach for runway 28 into the flight management system.

According to information from US Navy and Federal Aviation Administration (FAA) certified audio ATC recordings, about 2129, the RP controller advised the NIP radar arrival (RA) controller that flight 293 was 15 miles southwest of NIP for the RNAV approach to runway 28. The RA controller responded that the flight was radar identified. About 2130, the RP controller advised the flight crew that the previously mentioned precipitation was moving east and asked if they wanted to change to runway 10. After clarifying the runway number, the captain responded, "yeah go ahead let's do it." The RP controller assigned the flight heading 270 then heading 250, which the captain acknowledged.

From 2132 to 2133, the JAX RP controller and NIP RA controller coordinated the flight's change to runway 10. From 2134 to 2137, the RP controller provided the flight crew a series of heading changes to join the final approach course, which the first officer acknowledged. At 2137:34, the RP controller advised the flight crew that they were 7 miles from the final approach fix and cleared the flight for the RNAV runway 10 approach, which the first officer acknowledged. The JAX RP controller also confirmed with the NIP RA controller that the flight was set up for runway 10.

At 2137:48, the RP controller instructed the flight crew to contact NIP ground controlled approach (GCA). The captain requested a VHF frequency, which the RP controller provided. The first officer contacted the NIP GCA at 2138:32; the NIP RA controller responded with the NIP altimeter setting and advised that the RNAV approach would be using precision approach radar monitoring. (Precision approach radar is a fixed-base primary approach aid used by the US Navy during poor visibility conditions to provide vertical and lateral guidance, as well as range, to aircraft on final approach).

The RA controller also provided rollout and missed approach instructions and advised the flight crew that the short-field arresting gear on runway 10 was rigged (according to a Miami Air operations bulletin, arresting gear on runways places no limitations on Boeing 737 takeoff or landing operations; see Airport Information). The first officer acknowledged, then the captain sought clarification, asking the RA controller, "and that's for the ah first thousand feet, correct?", which the RA controller confirmed.

While the RA controller was providing arrival instructions, the CVR recorded a sound consistent with an altitude alert at 2139:06. At 2139:38 the NIP radar final (RF) controller assumed control of the flight from the RA controller and advised the flight crew that the "wheels should be down" (ATC procedures at US military facilities require a wheels-down check before descent on final approach for aircraft conducting radar-monitored approaches). The first officer acknowledged, and the CVR recorded sounds consistent with landing gear extension at 2139:48. At the same time, the RF controller cleared the flight to land on runway 10 and indicated a wind direction of 240° at 10 knots. The first officer acknowledged the landing clearance. A sound consistent with an altitude alert was recorded again at 2140:04.

At 2140:15, the RF controller advised the flight crew that they were "well above" the 3° glidepath to runway 10; at 2140:25, the precision approach path indicator (PAPI) lights would have appeared to the flight crew as four white lights, indicating the airplane's glidepath exceeded 3.5°. Automatic dependent surveillance-broadcast (ADS-B) and flight data recorder (FDR) data indicated that the airplane was about 3.5 nautical miles (nm) from the runway 10 displaced threshold about this time and was descending through 1,390 ft msl (1,369 ft above the touchdown zone elevation of 21 ft) at an indicated airspeed of 158 knots and descent rate of 1,062 ft per minute (fpm). The airplane's true airspeed about this time was 167 knots, and the groundspeed was 174 knots due to a 7-knot tailwind.

According to the Boeing 737 flight crew operations manual (FCOM), the flaps 30 landing reference speed ($V_{REF}30$) was 148 knots calibrated airspeed at the airplane's landing weight of 143,200 lbs, and the target approach speed ($V_{REF}30$ + 5 knots) was 153 knots calibrated airspeed (which is the indicated airspeed of an aircraft that is corrected for position and instrument error).

At 2140:25, a sound consistent with the autopilot disconnect warning was recorded. The airplane's descent rate increased from 1,100 to 1,400 fpm at 2140:30. At 2140:31, the captain called for the Landing checklist, and the first officer responded, "ah…speedbrakes ah armed, landing gear down three green, flaps thirty." At 2140:40, the airplane was about 1,100 ft msl and about 2.8 nm from the runway 10 displaced threshold; its descent rate decreased to 1,000 fpm, its indicated airspeed decreased to the target approach speed of 153 knots, and the groundspeed decreased to 166 knots. The airplane was closer to the nominal 3° glidepath, and the PAPI would have appeared as three white lights and one red light. Between 2140:46 and 2141:39, the indicated airspeed increased steadily from 153 to 170 knots, and the groundspeed increased from 166 to 180 knots. According to the NTSB Performance Study, both groundspeed and airspeed increased during this time at approximately the same rate. Therefore, this increase was a result of pitch control inputs. At 2141:09, at an altitude of about 680 ft msl and about 1.6 nm from the displaced threshold, the airplane deviated further above the 3° glidepath such that the PAPI lights would have appeared to the flight crew as four white lights and would retain that appearance throughout the rest of the approach.

For most of the approach from an altitude of 1,400 ft msl (3.5 nm from the displaced threshold) to the displaced threshold, the airplane was offset about 100 ft to the right of the extended runway centerline. At 2141:17, when the airplane was about 1 nm from the displaced threshold, its roll angle dipped to 12° right, and the airplane deviated farther to the right. This deviation reached 220 ft right of the runway centerline at 2141:28 when the airplane was about 0.5 nm from the displaced threshold and at an altitude of 360 ft msl. The airplane then rolled to about 9° left and corrected back toward the centerline. From 2141:18 to 2141:38, the airplane's flightpath angle steepened from -2° to -5°.

Six enhanced ground proximity warning system (EGPWS) "sink rate" alerts were recorded on the CVR starting at 2141:35 and ending at 2141:42; the descent rate peaked at 1,580 fpm about this time. The airplane crossed the displaced threshold at 2141:38, at an altitude of 140 ft msl (about 120 ft above the runway), an indicated airspeed of 170 knots (17 knots above the target approach speed), a groundspeed of 180 knots, and a descent rate of 1,450 fpm (according to Miami Air's stabilized approach criteria, the descent rate should not exceed 1,000 fpm below 1,000 ft above field level). According to the NTSB Performance Study, during the approach, the tailwind averaged about 5 knots until a few seconds before touchdown, when the tailwind increased to about 12 -13 knots, possibly as a result of the wind veering into the west and providing a more direct tailwind component.

Touchdown occurred at 2141:43.1, about 20 ft right of centerline, 1,580 ft past the displaced threshold and 394 ft beyond the runway's short field arresting gear; according to the FCOM, the target touchdown point is 1,000 ft from the threshold and "should occur within -250 ft to +500 ft of the target touchdown point). At touchdown, the airplane's indicated airspeed was 164 knots (11 knots above the nominal approach speed), and the groundspeed was 180 knots. After touchdown, the airplane moved left until reaching 10 ft left of centerline then started moving back toward the right.

FDR data indicate that No. 2 (right) throttle idle reverse thrust was commanded at 2141:46. At 2141:47, about 4 seconds after touchdown, the speedbrake handle moved aft to 46° and the speedbrakes deployed. Detent 2 reverse thrust (the position specified for normal operations in Miami Air's operations manual) was commanded about 2141:48. FDR data indicate that the autobrakes were applied at 2141:48 then pressure from the left normal (manual) brake metering valve increased to 905 lbs per square inch and, by design, disengaged the autobrakes at 2141:49.

The brakes were manually controlled by the flight crew for the remainder of the landing. The captain stated during postaccident interviews that he applied brake pressure after touchdown, but the airplane did not decelerate. He did not notice any antiskid activation. He stated he also deployed the No. 2 engine thrust reverser and applied enough pressure to the thrust reverser lever that it left a mark on his fingers. He stated that the airplane began to "slide a little to the right" and that he corrected with rudder to get the airplane back on centerline.

The airplane crossed the runway centerline from left to right at 2141:50.3, about 3,650 ft past the displaced threshold and 2,070 ft past the touchdown point. Between 2141:55 and 2141:58, maximum reverse thrust was commanded on the No. 2 engine. Between 2141:59 and 2142:00, the right throttle moved briefly back to the forward idle thrust position and the right thrust reverser temporarily stowed. Maximum reverse thrust on the No. 2 engine was again commanded at 2142:02 and was maintained until 2142:12, when the reverse thrust was reduced to the detent 2 level where it remained until the end of the data. The airplane began moving back toward the centerline and was about 55 ft right of the centerline when it crossed the end of the runway at 2142:10.4, 8,006 ft past the displaced threshold.

After departing the paved surface, the airplane impacted the seawall at 2142:19.2; it was 90 ft to the right of the centerline, 9,170 ft past the displaced threshold, and 1,164 ft past the end of runway 10. The first officer stated during postaccident interviews that, after the airplane came to rest, the captain called for an evacuation.

During postaccident interviews, the captain stated that he never thought to call for a go-around and that, as far as he knew, the runway was not contaminated. He stated that he “had his hand on the [weather] radar a couple of times” during the approach; however, there was not a “solid line” of weather, and he could see the city in the distance. He also stated that it started raining “very hard” on short final approach and that he turned on the wipers.

The first officer stated that they visually acquired the runway lights about 3 to 4 miles outside the final approach fix. He also stated that about 1 mile from the runway, the flight encountered a “rain shower” and that the airplane drifted to the right. In response, the captain corrected back to the extended centerline. Both pilots stated that none of the ATC communications included runway condition or braking action reports, and, according to CVR data, neither pilot requested this information.

According to the mechanic who was seated in the jumpseat, he could see the runway lights, but he could not recall how far out on final approach they were when he first saw them. He recalled they were in “heavy rain” and the captain had turned on the wipers to the highest setting. Other than the reverser light on the overhead panel, the mechanic did not observe any lights in the cockpit during the approach or after the airplane landed. When asked, he did not recall seeing the green auto arm light for the speedbrake illuminate.

A flight crew that was scheduled to take flight 193 passengers to Norfolk Naval Station, Norfolk, Virginia, was in an airplane parked on the ramp when flight 293 landed. The captain for the Norfolk flight stated that there had been a lot of lightning in the area before flight 293 landed but not at the time of the landing. However, the captain and first officer stated that it was “blinding rain” when flight 293 landed and that the accident airplane first became visible to them just before landing. The flight crew of a Navy P8 (a military variant of the Boeing 737) that landed on runway 28 at 2108 stated after the accident that “no degradation in braking action was observed” during their landing. ATC did not provide a braking action report to the P8 crew before their landing and did not request a braking action report from them after their landing.

According to interviews with the flight attendants, all four were sitting in their respective jumpseats during landing. Two were seated in the front of the airplane, positions 1L and 1R, and two were in the rear of the airplane, positions 2L and 2R. The forward flight attendants stated that after touchdown, they felt the airplane drift to the right and, within a few seconds, they felt “heavy aircraft movement” to the left and then to the right again. They eventually felt two “crashes,” the cabin went dark, and there was no communication from the flight crew.

Shortly after, the captain came out of the cockpit and instructed them to open the doors and evacuate the airplane. The forward flight attendant seated on the left side of the airplane opened the forward left door (1L), and the slide inflated then twisted. The flight attendant could not detach the slide from the airplane, so she moved to open the forward right door (1R); after opening the door, the 1R slide inflated then began to deflate. The 1L flight attendant attempted to launch a life raft from the 1R door, but it also deflated (the 1R flight attendant was holding passengers back during this time). As a result, the 1L flight attendant then redirected passengers to the overwing exits.

The flight attendants in the rear of the airplane realized the airplane was in water after landing; they blocked the rear exits (2L and 2R) and instructed the passengers to put on their life vests and move toward the overwing exits for evacuation. Passengers had opened the two overwing exits and some were already standing on the wing. Two life rafts were retrieved from the mid-cabin ceiling compartment; the flight attendants inflated the life rafts and deployed them off the trailing edges of both wings. Passengers were loaded onto the rafts and, once they were full, the flight attendants unhooked the lines and released them to firefighters who were standing in the water. These two rafts were shuttled back and forth to the shore with passengers onboard.

A fourth raft was retrieved and launched from the right overwing exit. This life raft began to deflate after passengers were in the raft; however, passengers were able to paddle the raft to shore (with the assistance of two passengers who jumped in the water and pushed the raft to shore). A rescue boat arrived and transported six remaining passengers to the shore while the captain, mechanic, and the 2R flight attendant conducted a final cabin check to ensure all passengers had evacuated. They were subsequently transported to shore by a rescue boat. All crew and passengers were evaluated for injuries at the triage staging area established near the waterfront.

Pilot Information

Certificate:	Airline transport; Commercial; Private	**Age:**	55,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	November 16, 2018
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	October 14, 2018
Flight Time:	7500 hours (Total, all aircraft), 2204 hours (Total, this make and model), 45 hours (Last 90 days, all aircraft), 5 hours (Last 30 days, all aircraft), 5 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	47,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	Yes
Medical Certification:	Class 1	**Last FAA Medical Exam:**	January 30, 2019
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	7500 hours (Total, all aircraft), 18 hours (Total, this make and model), 18 hours (Last 90 days, all aircraft), 18 hours (Last 30 days, all aircraft), 5 hours (Last 24 hours, all aircraft)		

The Captain

The captain was hired by Miami Air in March 2008 as a first officer. He completed upgrade operating experience training for captain on November 20, 2015. Before being employed at Miami Air, he flew for AmeriJet International and IBC Airways. He earned his private pilot license in Argentina flying piston aircraft and earned his FAA certificates after moving to the United States. At the time of the accident, the captain was based at Miami International Airport (MIA), Miami, Florida, and held an airline transport pilot certificate and type ratings in the B 727, B-737, SF-340, and SA-227.

While employed at Miami Air, in addition to pilot duties, the captain has been a ground instructor, flight instructor, simulator instructor, and line check airman. Two weeks before the accident, he became Miami Air's only aircrew program designee (that is, possessing the authority to conduct certification evaluations on behalf of the FAA).

According to the captain's training records, his most recently completed training included weather radar training on May 31, 2018, and safety management system (SMS) and emergency training and drills on June 1, 2018.

The Captain's Pre-Accident Activities

The captain reported he was off duty on May 1. He said there was nothing unusual about his activities during this time and did not recall his sleep schedule on April 30. The captain's cellphone records (which included outbound calls and text messages and inbound calls not routed to voicemail longer than 30 seconds) for April 30 indicated activity beginning at 0730 and ending at 1757 with two extended breaks in activity (extended breaks in activity include any breaks longer than 60 minutes).

Cellular telephone records for May 1 indicated activity beginning at 0741 and ending at 2154, with several extended breaks in activity. The captain reported going to bed about 2130 and awakening between 0500-0530 on May 2. He took a commercial flight to JAX that departed MIA about 1028 and arrived at 1149. He checked into a hotel about 1253. He stated that he discussed training with the accident first officer from about 1630 to 1730, had dinner, watched TV, and talked with his wife. The captain reported going to sleep between 2100-2130. Cellphone records for May 2 indicated activity beginning at 0729 and ending with a 1-minute incoming call about 2338, with several extended breaks in activity.

On May 3, the day of the accident, the captain awoke about 0500. He checked out of the hotel at 0716 and was scheduled to report to NIP at 0755. The captain's cellphone records for May 3 indicated activity beginning at 0653 until 1330, with several extended breaks in activity.

The First Officer

The first officer was hired by Miami Air on October 13, 2018, and began training on January 3, 2019; recently completed training including initial crew resource management, emergency training and drills, weather radar training, SMS, and RNAV approach simulator training. Although the first officer had not flown with the captain before the accident itinerary, the captain administered the first officer's checkride for his type rating in a B-737 simulator on February 27, 2019, with an FAA inspector present. The first officer had about 18 hours flight experience in the B-737 at the time of the accident.

The first officer earned a private pilot certificate in Argentina. After moving to the United States, he obtained his FAA certificates, including a flight instructor certificate. After he obtained his ratings, he was a freelance flight instructor in the Miami area until being hired by Miami Air.

The First Officer's Pre-Accident Activities

The first officer stated his sleep was routine during the 3 days before the accident; he went to sleep about 2230 and woke up about 0630. He reported having no issues staying asleep and indicated nothing that would have caused him to not follow his routine. The first officer's cellphone records for April 30 indicated activity beginning at 0613 and ending at 2244 with several extended breaks. The cellphone records for May 1 indicated activity beginning at 0735 and ending at 1700 with two extended breaks in activity.

On May 2, he took a commercial flight to JAX with the captain. He traveled with the captain via shuttle service from the airport to a hotel and reported going to bed about 2230. His cellphone records for May 2 indicated activity beginning at 0735 until 1700 with several extended breaks in activity. The first officer reported awakening about 0630 on May 3, the day of the accident. He checked out of the hotel about 0717. He traveled with the captain via shuttle to NIP and reported for duty at 0755. Cellphone records indicated activity beginning at 0529 and ending at 1950 with several extended breaks in activity.

Aircraft and Owner/Operator Information

Aircraft Make:	Boeing	**Registration:**	N732MA
Model/Series:	737 81Q	**Aircraft Category:**	Airplane
Year of Manufacture:	2001	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	30618
Landing Gear Type:	Tricycle	**Seats:**	179
Date/Type of Last Inspection:	April 27, 2019 Continuous airworthiness	**Certified Max Gross Wt.:**	174200 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:	38928 Hrs at time of accident	**Engine Manufacturer:**	Cfm Intl
ELT:	C91A installed, activated, did not aid in locating accident	**Engine Model/Series:**	CFM56-7B26
Registered Owner:	Wells Fargo Trust Co Na Trustee	**Rated Power:**	26000 Lbs thrust
Operator:	Miami Air International	**Operating Certificate(s) Held:**	Flag carrier (121), Supplemental

According to the dispatch paperwork for the flight, the airplane had the following MEL and configuration deviation list deferred maintenance items:

- inoperative Wifi (opened April 30, 2019)
- SATCOM fault light illuminated (opened May 2, 2019)
- No. 1 engine reverser light illuminated (opened May 3, 2019)
- right air conditioning pack inoperative (opened May 3, 2019)

The airplane's maintenance records listed three additional MEL items:

- ETOPS [extended-range twin-engine operational performance standards] verification flight to be accomplished due to change of Nos. 1 and 2 engines (opened May 1, 2019)
- aircraft downgraded to non-ETOPs (opened May 3, 2019)
- no duct pressure indication both engines running (opened May 3, 2019)

All open MEL items were being tracked per Miami Air's FAA-approved MEL procedures, dated May 15, 2018.

Normal (Manual) Brake System

The manual brakes are controlled by the flight crew using the brake pedals in the flight deck. Brake pedal movement is transmitted by cables to the left and right brake system metering valves located in the main landing gear wheel well. The metered hydraulic pressure passes through a shuttle valve to the respective inboard and outboard antiskid valves. Between the shuttle valve and the antiskid valves is a brake pressure transducer (one for the left brake system and one for the right brake system). Between each antiskid valve and brake assembly is a hydraulic fuse, to prevent hydraulic fluid loss if there is an external leak downstream of the fuse, and an alternate brake shuttle valve to allow brake pressure from the alternate brake system, if required. Each wheel has one brake assembly. The brake assemblies are rotor-stator units that use hydraulic pressure to push the rotors and stators together, causing the wheel to slow.

Autobrake System

The autobrake system supplies metered brake pressure to stop the airplane after landing or if a rejected takeoff (RTO) occurs. The autobrake system monitors wheel deceleration and controls metered pressure to maintain the target deceleration rate selected by the pilot on the AUTO BRAKE select switch until the airplane comes to a full stop. The pilot can select a setting of RTO, OFF, 1, 2, 3, or MAX depending on the desired deceleration rate. The autobrake system arms for landing when there are no associated faults in the autobrake system or the normal antiskid system, and all the following conditions occur:

- The AUTO BRAKE select switch is moved to a landing deceleration position (1, 2, 3, or MAX)
- Both air/ground systems in air mode, or both thrust levers at idle, or one or both air/ground systems in the ground mode for less than or equal to 3 seconds
- Valid input from the left air data inertial reference unit
- Normal brake metered pressure is less than 750 psi

The autobrake function applies the brakes when these conditions occur:

- Landing autobrake is armed
- Both thrust levers at idle
- Either air/ground system continuously indicates ground for 0.2 second (if wheel spin-up occurs more than 1 second before ground is sensed) or 0.7 second (if wheel spin-up occurs less than 1 second before ground is sensed)
- Wheel spin-up detection occurs or the spin-up latch sets. Wheel spin-up detection occurs when one wheel on each main landing gear increases to 60 knots or greater and the wheel speed stays above 30 knots. The spin-up latch sets 3 seconds after the air/ground system is in the ground mode and the wheel spin-up detection occurs.

Antiskid System

The antiskid system monitors wheel deceleration and controls the metered brake pressure to prevent wheel skids during brake application. The antiskid system is operational whenever the associated electrical buses are powered and requires no flight crew action. When brake pressure is released to a wheel that is skidding, the system permits the wheel speed to increase, which stops the skid condition. When the normal braking system is active, an antiskid valve is available for each wheel brake.

When commanded by the antiskid autobrake control unit (AACU), the antiskid valve releases pressure to its associated wheel brake through the parking brake valve. A transducer in each main landing gear wheel axle supplies wheel speed data to the AACU. If the test card in the AACU detects a fault in the antiskid system, an ANTISKID INOP amber light illuminates on the flight display. When certain faults (including an open antiskid inboard or outboard circuit breaker) are detected in the antiskid system, the autobrake system becomes inoperative.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Night
Observation Facility, Elevation:	NIP,23 ft msl	**Distance from Accident Site:**	
Observation Time:	21:22 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Scattered / 800 ft AGL	**Visibility**	5 miles
Lowest Ceiling:	Broken / 1800 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	4 knots /	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	350°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.98 inches Hg	**Temperature/Dew Point:**	24°C / 22°C
Precipitation and Obscuration:	Heavy - Thunderstorm - Rain		
Departure Point:	Guantánamo, OF (NBW)	**Type of Flight Plan Filed:**	IFR
Destination:	Jacksonville, FL	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	Class D

The observations from NIP surrounding the accident time indicated marginal visual flight rules conditions with heavy rain (0.53 inch of precipitation reportedly fell between 2122 and 2145) and thunderstorms. A “T1 SET” thunderstorm warning was issued for NIP at 2122. (As defined in guidance issued by the Department of Defense [OPNAV Instruction 3140.24F], a T1 thunderstorm warning indicated the potential for “destructive wind and accompanying thunderstorms” within 10 nm or expected within an hour of the warning’s issuance, as well as associated lightning/thunder, torrential rain, hail, severe downbursts and sudden wind shifts). A gusty west-northwest wind was recorded at NIP about 3 minutes after the accident.

Terminal Aerodrome Forecast

NIP was the closest airport terminal aerodrome forecast (TAF). The NIP TAF valid at the time of the accident was issued by a certified weather observer at NIP at 1900 and was valid for a 24-hour period. Between 1900 on May 3 and 0000 on May 4, 2019, the forecast indicated wind from 180° at 4 knots, greater than 7 miles visibility, thunderstorms in the vicinity, scattered clouds at 1,500 ft agl, a broken ceiling of cumulonimbus clouds at 3,000 ft agl, and broken clouds at 10,000 and 25,000 ft agl. The forecast indicated a minimum altimeter setting of 29.91 inches of mercury (in Hg).

Temporary conditions were forecast for the same period, which included variable wind of 10 knots with gusts to 20 knots, 3 miles visibility in moderate rain showers and mist, scattered clouds at 1,000 ft agl, a broken ceiling of cumulonimbus clouds at 2,000 ft agl, broken clouds at 8,000 ft agl, and broken clouds at 25,000 ft agl.

Between 2125 and 2145, 714 lightning flashes occurred near NIP. The closest lightning flash to the accident flight (1,637 ft north of its track) occurred at 2141:17.

Surface Observations

The closest official weather station to the accident site was an automated surface observing system (ASOS) at NIP; these reports were supplemented by official certified contract weather observers. The NIP ASOS site was located between the airfield's two runways at the centerfield location about 4,500 ft west-northwest of the accident site at an elevation of 23 ft and had a 6° westerly magnetic variation. The 2122 NIP meteorological aerodrome report (METAR) was the last observation recorded before the accident and indicated the following:

> wind from 350° at 4 knots, 5 miles visibility, heavy rain and thunderstorms, mist, scattered clouds at 800 agl, broken ceiling of cumulonimbus clouds at 1,800 ft agl, overcast skies at 3,000 ft agl, temperature of 24°C, dew point temperature of 22°C, and an altimeter setting of 29.98 inHg. Remarks: automated station with a precipitation discriminator, thunderstorms began at 2104, frequent lightning overhead, thunderstorm overhead moving east, thunderstorm conditions are forecasted within 10 miles of NIP, 0.10 inch of precipitation since 2053 EDT, temperature 24.4°C, dew point temperature 22.2°C, maintenance is needed on the system.

On the day of the accident, the ASOS at NIP recorded rainfall amounts at 1- and 5-minute intervals. The aircraft performance study presented rainfall rates computed from the recorded rainfall amounts. Between 2138 and 2139, about 4 minutes before the accident, the 1-minute recorded rainfall rate was as high as 2.4 inches per hour. At 2141, about 1 minute before the accident, the 1-minute rainfall rate was 1.2 inches per hour; it decreased to 0.6 inch per hour at 2142 then increased to 1.8 inch per hour at 2143.

Just after the accident, the 2145 METAR contained the following information:

> wind from 290° at 8 knots with gusts to 16 knots, 3 miles visibility, heavy rain and thunderstorms, mist, scattered clouds at 800 ft agl, broken ceiling of cumulonimbus clouds at 1,500 ft agl, overcast skies at 3,200 ft agl, temperature of 24°C, dew point temperature of 22°C, and an altimeter setting of 29.99 in Hg.

> Remarks: automated station with a precipitation discriminator, thunderstorms began at 2104 EDT, frequent lightning in cloud and overhead, thunderstorm overhead moving east, thunderstorm conditions are forecasted within 10 miles of NIP, 0.63 inches of precipitation since 2053 EDT, temperature 24.4°C, dew point temperature 22.2°C, maintenance is needed on the system.

Neither the flight crew of the accident airplane or the flight crew of the Navy P8 (who landed approximately 30 minutes prior) reported encountering windshear during their respective approaches. Although there was no windshear detection equipment installed at NIP, windshear detection equipment installed on the airplane did not detect windshear.

Airport Information

Airport:	JACKSONVILLE NAS (TOWERS FLD) NIP	**Runway Surface Type:**	Asphalt
Airport Elevation:	22 ft msl	**Runway Surface Condition:**	Wet
Runway Used:	10	**IFR Approach:**	PAR;RNAV
Runway Length/Width:	9003 ft / 200 ft	**VFR Approach/Landing:**	

Owned by the United States Navy, NIP is located about 4 miles south of Jacksonville, Florida. It is serviced by a military airport traffic control tower in operation 24 hours a day. Approach radar services to the accident flight were provided by Jacksonville approach control.

On March 28, 2019, a notice to airmen (NOTAM) was issued stating that the newly commissioned ATIS at NIP was “now operable.” This NOTAM was included in the dispatch paperwork for the flight.

NIP runway 10 is ungrooved and has a displaced threshold 997 ft from the threshold, leaving a landing length of 8,006 ft. The runway has an average gradient of -0.165% (downhill) over the 8,006-ft landing length. The PAPI glidepath crosses the displaced threshold about 54 ft above the runway. Runway 10 is equipped with short field arresting gear, which crosses the runway 1,186 ft past the displaced threshold when rigged. The runway is concrete for the first 1,660 ft and last 1,000 ft and is asphalt in between.

Wreckage and Impact Information

Crew Injuries:	1 Minor, 6 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	136 None	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	1 Minor, 142 None	**Latitude, Longitude:**	30.231666,-81.660278

Light white landing gear track marks were visible on the pavement starting 1,592 ft from the displaced threshold (12 ft past the touchdown point of 1,580 ft computed by the onboard performance tool [OPT]) to the end of the pavement. The airplane's tracks showed variation in position relative to the right of centerline after touchdown and exited the paved surface about 55 ft to the right of centerline. The tracks continued in the grass area, deviating farther to the right of centerline and extending to the point at which the airplane struck the rock berm and entered the river, 90 ft right of centerline. Figure 1 shows the transition of track marks from the pavement to the grass and figure 2 shows the airplane at final rest in St Johns River.

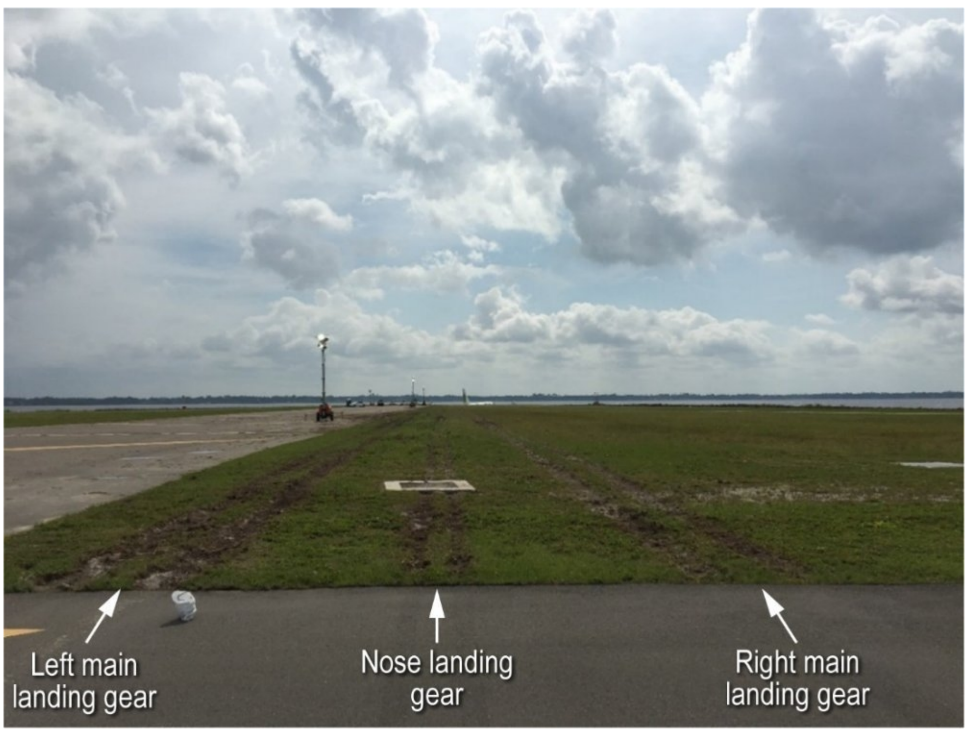

Figure 1. Photograph of tire marks from the accident airplane's landing gear

Figure 2. Photographs of accident airplane in St. Johns River

The airplane was mostly intact but sustained substantial damage. Portions of the engine cowlings, the radome, and both main landing gear separated during the accident sequence and were in the water adjacent to the airplane or on the rock embankment. Three life rafts were recovered in the water around the airplane. The L1 and R1 (forward) doors and the four overwing emergency exits were open. The L2 and R2 (aft) doors were closed. The L1 door evacuation slide was inflated and partially attached to the door sill and the R1 door evacuation slide was hanging uninflated from the door sill.

Flight recorders

The accident airplane was equipped with a Honeywell 4700 solid-state FDR that contained about 27 hours of flight data. The accident flight was the last flight of the recording and its duration was about 2 hours and 34 minutes. The data were extracted normally.

The airplane was also equipped with a Honeywell model 6022 CVR capable of recording 120 minutes of digital audio. It contained a two-channel recording of the last 120 minutes of operation and contained a separate three-channel recording of the last 30 minutes of operation. The CVR exhibited no water, structural, or heat damage, and the audio information was extracted normally and without difficulty.

Tests and Research

Aircraft Performance Study

The NTSB conducted a performance study to estimate the airplane's position, speed, and deceleration during the approach and landing and determine the airplane's response to control inputs, external disturbances, ground forces, and other factors that could affect its trajectory. The study considered data from the following sources: wreckage location and condition, ground scars/markings, FDR, CVR, runway macrotexture, cross-slope, and friction measurement information, weather information, airplane thrust and aerodynamic performance information, output from aircraft performance computer programs and simulations, models of braking friction on wet runways, and models of water drainage from runways.

Reverse thrust on the right engine and idle forward thrust on the left engine (due to the inoperative thrust reverser) created an asymmetric thrust condition that acted to yaw the airplane nose right. Throughout the landing roll, the left brake pressure was consistently higher than the right brake pressure (though at a couple of points the pressures were briefly matched), and left rudder pedal was consistently applied.

The rainfall rate at the time of the accident and the macrotexture depth and cross-slope of runway 10 could have produced water depths on portions of the runway close to or exceeding the 3-mm (1/8-inch) depth considered to be a flooded condition. As the airplane travelled down the runway, drifting back and forth from the centerline, it developed a drift angle as high as 8° (the drift angle is the difference between the airplane's track over the ground and its heading). This drift angle developed a cornering force on the main gear tires, which helped the airplane correct back to the centerline; however, the cornering demand on the tires likely reduced the tire braking friction available to slow the airplane. According to a Boeing simulation conducted at the NTSB's request, the maximum braking friction coefficient can be expected to decrease with increasing drift angle. On a wet runway and at an 8° drift angle, the maximum braking friction coefficient can be reduced by about 24%.

The maximum wheel braking friction coefficient developed by the airplane during the landing ground roll was significantly less than the maximum wheel braking friction coefficient underlying the wet-runway landing distances published in the Boeing 737 FCOM and computed by Miami Air's OPT application (see Organizational and Management Information). The maximum wheel braking friction coefficient achieved during the accident was also lower than the flooded runway models described in the TALPA RCAM, AMC 25.1591, and Boeing's simulation model for nondynamic hydroplaning conditions.

About 5 seconds after touchdown, the computed wheel braking friction coefficient was about 0.05 and decreased to about 0.04 about 10 seconds later. It increased to about 0.08 at 2141:58 (the rolling friction coefficient on unbraked tires is about 0.02). Between 2142:00 and 2142:07, the wheel braking friction coefficient decreased to about 0.05 before increasing to about 0.09 at 2142:11 just before the airplane departed the pavement into the grass.

The white tire marks on the runway over the entire length of the landing roll, and the lateral load factor developed during the landing roll (as a result of the cornering forces on the main gear tires), indicate that the tires were in contact with the runway (likely through a thin film of water) rather than being lifted entirely off the runway as occurs during dynamic hydroplaning. The evidence against dynamic hydroplaning combined with the extremely low wheel braking friction coefficient that was achieved suggest that the airplane experienced viscous hydroplaning during the landing roll. Viscous hydroplaning is associated with the buildup of water pressure under the tire due to viscosity in a thin film of water between a portion of the tire footprint and the runway surface. On a wet runway, the maximum wheel braking friction coefficient decreases with increasing speed due to viscous hydroplaning.

The NTSB's performance study indicated that, even with the airplane's excessive approach speed, the tailwind, and delayed speedbrake deployment, the airplane still would have stopped on the runway pavement, with about 17% of the available runway remaining, if it had achieved the maximum wheel braking friction coefficient underlying the "good" braking action landing distances published in the FCOM. However, due to the presence of standing water (with depths close to that defined as a flooded condition) on portions of the runway and the resulting viscous hydroplaning, the airplane would not have been able to stop before reaching the end of the paved runway surface even if it had landed on target speed within the operator's specified touchdown zone and in calm wind conditions.

Miami Air International received FAA and Department of Transportation certification on October 11, 1991, and conducted its first commercial flight on October 15, 1991. In January 1993, Miami Air was approved to provide charter service to transport Department of Defense (DOD) passengers. At the time of the accident, Miami Air had five aircraft, all of which were B737-800s. On March 24, 2020, Miami Air International filed for Chapter 11 Bankruptcy protection and ceased operations on May 8, 2020.

A biennial review of Miami Air conducted by personnel from the DOD Commercial Airlift Division in August 2016 recommended that the company met "the DOD commercial Air Transportation Quality and Safety Requirements for continued participation in the DOD Air Transportation Program." Miami Air conducted pilot training in-house using its own instructors and leased local simulators to satisfy pilot training requirements.

Landing Checklist

The Miami Air, 737 Operations Manual, "Normal – Procedures – Amplified Procedures," dated March 28, 2018, stated the following concerning the Landing checklist:

> PM reads items with responses as indicated.
>
> When cleared to land, the Captain turns on the Landing Lights, Runway Turnoff Lights and Taxi Light.
>
> F/A Signal ....GIVEN PM
>
> "Flight Attendants Landing Check Please" at approximately 10 miles prior to landing.
>
> Engine Start switches .... CONT PM
>
> Speedbrake .... ARMED, GREEN LIGHT PM
>
> Armed by the Captain.
>
> Landing Gear .... DOWN, 3 GREEN PF
>
> Flaps ....________°, GREEN LIGHT PF

Stabilized Approach Criteria

The Miami Air FOM, Chapter 2, dated April 14, 2016, stated the following regarding stabilized approaches:

The approach profiles contained in the Flight Crew Training Manual are intended as guidelines for configurations during approaches. Weather and traffic conditions may require deviations from the standard profiles.

However, no later than 1,000 feet AFL [above field level], the airplane must be:

- Fully configured with the Landing checklist complete.
- At a sink rate of no greater than 1,000 feet per minute*.
- Stabilized at the proper approach speed.
- Trimmed for zero control forces and;
- Engines spooled up.
- On glideslope

* momentarily exceeding 1,000 feet per minute is permitted as long as the rate of descent is immediately reduced to at or below 1,000 feet per minute.

Pilots should be alert for higher than normal descent rates as an indication of possible windshear. On any runway which has operating vertical descent guidance equipment (PAPI, [visual approach slope indicator] or [instrument landing system] glide slope) the aircraft will be flown at or above the glide slope until 200 feet AFL. "Duck Under" approaches are not authorized.

It is critical to flight safety that both the PF and the PM should be able to call for a go-around if either pilot believes an unsafe condition exists. The crew will comply with the following:

1. Either the PF or the PM may make a Go-Around callout, and

2. The PF's immediate response to a Go-Around callout by the PM is execution of a missed approach.

If the aircraft is not stabilized by 1,000 feet AFL or at any point thereafter, a Missed Approach is MANDATORY.

Ground Proximity Warning

The Miami Air FOM, Chapter 2, section "Ground Proximity Warning," stated:

The Ground Proximity Warning System does not require crew inputs and is silent during all normal flight maneuvers. If a warning is activated, it requires immediate positive action by the crew unless visual conditions exist which positively confirm the reason for the warning. In the absence of such visual conditions, an immediate positive pull up will be executed and a climb established until the warning ceases.

The Miami Air FOM, Chapter 2 “Normal Operations,” provided the following definitions and procedures for using the TALPA standard:

New Definitions

Runway Condition Code (RCC) - the RCC is a numerical descriptor of runway conditions based on defined contaminants for each runway third.

Wet Runway - A runway is considered “wet” when more than 25% of the runway surface area is covered by any visible dampness or water that is 1/8 inch or less in depth. A damp runway that meets this definition is considered wet, regardless of whether or not the surface appears reflective. If frost is reported on a runway, the runway is also considered “wet.”

Contaminated Runway - A runway is considered “contaminated” when more than 25% of the runway surface is covered by either:

- more than 1/8 inch of water, dry or wet snow, or
- any depth of:
    - compacted snow
    - wet or dry snow over compacted snow
    - slush
    - ice
    - wet ice
    - slush over ice
    - water over compacted snow
    - dry snow or wet snow over ice

Dry Runway - A runway is considered “dry” if it is neither “wet” nor “contaminated.”

Procedures

- A Runway Condition Assessment Matrix (RCAM) will be used to determine and report runway condition.
- Through the NOTAM system, pilots will receive a numerical (0 through 6) runway condition report using numerical value Runway Condition Codes (RCC) derived from the RCAM.

- Pilots will give braking action reports using descriptive terminology (e.g. "good," "medium," "poor" and "nil"). "Medium" has replaced the term "Fair" in braking action reports, which pilots will continue to provide.

- At the heart of the TALPA [advisory and rulemaking committee] recommendations is the "Runway Condition Assessment Matrix" or simply the "Matrix." The "Matrix" identifies 7 "Runway Condition Codes." These Codes are derived from runway "Assessment Criteria" that includes type of contaminant (frost, slush, dry snow, wet snow, compacted snow, and ice), depth of contaminant and temperature. From the Runway Condition Codes, pilots can determine the anticipated runway braking action and more importantly the correct "Runway Condition" to enter in the OPT. The tower will issue an RCC Report for each 1/3 of the runway; touchdown, midpoint and rollout. For example, an RCC Report might read 5, 5, 3.

Guidance Concerning Arrival Landing Distance Assessments

The Miami Air FOM provided the following guidance to flight crews concerning performing an en route landing distance assessment:

> If conditions have not changed or have improved since accomplishing pre-departure calculations, it is not necessary to calculate the required landing distance.
>
> A new landing distance required calculation is mandatory if conditions have changed or worsened, such as:
>
> 1. Actual landing runway is shorter from the runway used for pre-departure calculation, or
>
> 2. Runway conditions have changed requiring greater runway length (less of a headwind, stronger tailwind, braking action reports have worsened), or
>
> 3. Flap configuration has changed due to non-normal configuration (e.g. asymmetrical flaps.), or
>
> 4. Destination airport has changed.
>
> **Note:** The en route landing distance calculation is not required if all of the following conditions exist:
>
> - Runway is 7,000 ft or longer
> - Landing flaps are either 30° or 40°
> - Airport elevation is 3000 feet msl or lower
> - Tailwind is 5 knots or less
> - Airport temperature is 40° C or less

- Braking action is good or better
- No more than one thrust reverser inoperative
- Max manual braking

The Miami Air FOM also stated the following:

> No landing will be attempted with a tailwind when the braking action is reported as anything less than “Good.”

The Miami Air quick reference handbook (referred to as the Redbook) provided the following information on landing distance calculations based on runway conditions:

Runway Conditions	DISPATCH (accomplished prior to takeoff)	ENROUTE (prior to beginning approach)*
Dry or Wet (Wet = Good)	***-800*** Use OPT **“Dispatch Related Landing Info”**	Use OPT “Enroute Related Landing Info” See Note 2.
Slippery	***-800*** Use OPT **“Enroute Related Landing Info”** See Note 1.	

1. When dispatching to an airport where the anticipated runway conditions are slippery (other than dry or wet), it is recommended to have a 15% safety factor (OPT adds 15% automatically). If this recommendation cannot be met, the flight may still be dispatched with Dispatcher approval, if the “wet” dispatch requirements can be met. The Dispatcher would normally approve if, at the ETA, Enroute Landing requirements can be satisfied (landing distance for the slippery conditions plus 15%).

2. [Note 2 repeats the same eight conditions cited in the FOM that would not require an en route landing distance calculation.]

Miami Air Postaccident Actions

Miami Air issued FOM Bulletin 19-05, “Approach Briefing update – Grooved Runway,” to all Miami Air flight crews, dated May 20, 2019. The bulletin stated, in part, the following:

> **Procedure**
>
> The Approach Briefing item:
>
> > “A discussion of unusual or abnormal conditions or any pertinent information,” now includes “landing on a non-grooved runway.”
>
> If landing on a non-grooved runway, the crew will accomplish the following:
>
> - An OPT Enroute Landing Distance calculation prior to the approach. (This gives the crew a better idea what Autobrake setting to use. Also, this step highlights if the Landing Distance Available vs Landing Distance Required is critical). If the ATIS or tower are reporting heavy rain at the airport, an approach may be made, however, a landing will not be attempted until conditions change. On very short flights, the OPT Enroute Landing Distance may be waived. For example, a flight from Fort Lauderdale to Miami may not allow enough time to perform the calculation. In that case, accomplish the enroute landing calculation before takeoff.
> - In accordance with standard procedure, when performing OPT calculations, assume one less engine reverser credit than the number operational.
> - Captain will make the landing if the runway condition is other than dry.
> - 40 degree flap landing, if the runway condition is other than dry.
> - Request the longest runway compatible with the reported airport winds and runway conditions, if the runway condition is other than dry.
> - No landing will be attempted with greater than a 5-knot tailwind component if the runway is other than dry.
> - Request a wind check and the field condition (i.e. rain condition or standing water on the runway) from the tower at 1000 feet AFL.
> - No landing will be attempted if the pilot observes heavy rain on the landing runway or the tower reports heavy rain on the landing runway.
> - At touchdown, apply MAX AUTO braking if the runway condition is other than dry. After touchdown, the Captain may revert from Max Auto braking to “manual braking” after making the determination that the aircraft will stop well short of the runway.

As noted previously, Miami Air International ceased operations on May 8, 2020.

Additional Information

Thunderstorm Avoidance Guidance

Section 10 of Advisory Circular 00-24C, “Thunderstorms,” notes, in part, the following concerning thunderstorm avoidance:

> Don’t land or takeoff in the face of an approaching thunderstorm. A sudden gust front of low-level turbulence could cause loss of control. Don’t attempt to fly under a thunderstorm even if you can see through to the other side. Turbulence and wind shear under the storm could be hazardous. …Don’t assume that ATC will offer radar navigation guidance or deviations around thunderstorms.

Safety Alerts for Operators (SAFO) Concerning Turbojet Performance on Wet Runways

SAFO 15009, issued in August 2015, was in effect at the time of the accident. Its purpose was to warn “airplane operators and pilots that the advisory data for wet runway landings may not provide a safe stopping margin under all conditions.” It further stated:

> The root cause of the wet runway stopping performance shortfall is not fully understood at this time; however, issues that appear to be contributors are runway conditions such as texture (polished or rubber contaminated surfaces), drainage, puddling in wheel tracks and active precipitation. Analysis of this data indicates that 30 to 40 percent of additional stopping distance may be required in certain cases where the runway is very wet, but not flooded. … data contained in the Aircraft Flight Manuals (and/or performance supplemental materials) may underestimate the landing distance required to land on wet, ungrooved runways.

The SAFO recommended that:

> Directors of safety and directors of operations (Part 121); directors of operations (Part 135, and 125), program managers, (Part 91K), and pilots (Part 91) should take appropriate action within their operation to address the safety concerns with landing performance on wet runways discussed in this SAFO.

The SAFO also suggested some ways of taking “appropriate action” to address the safety concerns, such as “assuming a braking action of medium or fair when computing time-of-arrival landing performance or increasing the factor applied to the wet runway time-of-arrival landing performance data.”

In July 2019, the FAA issued SAFO 19003, which replaced SAFO 15009. SAFO 19003’s purpose is nearly identical to that stated in SAFO 15009 but specifies that advisory data for wet runway landings may not provide a safe stopping margin “especially in conditions of moderate or heavy rain." In addition, SAFO 19003 updates the discussion to include reference to SAFO 19001 (which was issued in March 2019 and replaced SAFO 06012) and addresses the Takeoff and Landing Performance Assessment (TALPA) and Runway Condition Assessment Matrix (RCAM) framework:

> [TALPA] procedures implemented by the FAA on October 1, 2016, added new insight as to how flight crews can evaluate runway braking performance prior to landing. TALPA defines WET as 'includes damp and 1/8-inch depth or less of water,' while CONTAMINATED is 'greater than 1/8-inch of water.'
>
> Analysis of [landing overrun] incidents/accidents indicates that the braking coefficient of friction in each case was significantly lower than expected, and that 30 to 40 percent of additional stopping distance may be required if the runway transitions from wet to contaminated based on the rainfall intensity or reported water contamination (greater than 1/8-inch depth). For the operational in-flight landing assessment, determining whether the runway is wet or potentially contaminated is the pilot's responsibility. … Rainfall intensity may be the only indication available to the pilot that the water depth present on the runway may be excessive. The 1/8-inch threshold … is based on possibility of dynamic hydroplaning. This can be especially true in moderate rain if the runway is not properly crowned, grooved, constructed with a porous friction course (PFC) overlay, or when water run-off becomes overwhelmed. During heavy rain events, this may be true even on a properly maintained grooved or PFC runway.
>
> The TALPA RCAM recommends using landing performance data associated with medium to poor braking … if greater than 1/8-inch of water is anticipated to be on the runway. When planning to land on a smooth runway under conditions of moderate or heavy rain, or when landing on a grooved or PFC runway under heavy rain, pilots should consider that the surface may be contaminated with water at depth greater than 1/8 inch and adjust their landing distance assessment accordingly. Pilots should use all available resources to determine what condition they may expect upon landing…Go-around, holding, or diversion may be necessary if rainfall intensity increases beyond what might be acceptable for the intended operation.

Miami Air Dispatch/Onboard Performance Tool Landing Distances and Boeing 737-800 FCOM

The NTSB's aircraft performance study compared flight crew operating manual (FCOM) and OPT landing distances for various conditions. Both the FCOM and OPT contain airplane performance data that operators can use to ensure compliance with dispatch requirements and to perform en route landing distance assessments. The OPT calculates landing distances by determining the forces acting on the airplane throughout the landing roll and solving the equations of motion to determine the overall distance required to stop. The OPT calculation accounts for the effects of different variables such as weight, wind, runway slope, runway friction, and deceleration device usage, directly at each point in the calculation.

In contrast, the FCOM-determined landing distances are based on a predetermined reference distance required for a reference weight with maximum manual braking and no thrust reversers. Adjustments are then made to this reference distance to account for different weight, wind, friction, reverse thrust, and other conditions. In addition, the FCOM distances do not include a safety factor, whereas operators have the option to add a safety factor to the landing distances reported by the OPT. The landing distances displayed to the pilots by Miami Air's OPT included a 15% safety factor added to the computed landing distances.

The dispatcher who checked the landing distance and weight calculations for the accident flight stated that he used Miami Air's OPT software to determine the performance numbers. This dispatcher stated that although the previous dispatcher on duty had already done the calculations for the accident flight, he ran the numbers again and that they were "ok" for a wet landing.

The runway condition values in the OPT were: dry (6), wet (5), standing water, slush, compact snow, dry snow, good (5), good-medium (4), medium (3), medium-poor (2), and poor (1). However, the Miami Air FOM indicated that several of these options were not to be used:

> Upon receiving a [runway condition code] report, Miami Air pilots will "translate" the report into an equivalent braking action (e.g. good, good to medium, medium, medium to poor, poor or nil) for the OPT calculation.
>
> Note: Pilots should use "Dry," "Wet," "Slippery Good," "Slippery Medium" or "Slippery Poor" for OPT computations. Do not use "Standing Water," "Slush," "Compact Snow" or "Dry Snow."

The airplane performance study used conditions present at the time of the accident as well as maximum manual braking and auto speedbrakes to determine landing distances for different combinations of approach speed, tailwind, thrust reversers, and runway conditions (see Tests and Research for more information). The study concluded that with one thrust reverser, and good braking action (FCOM) or wet (5) or good (5) runway conditions (OPT), and a 10-knot tailwind, the airplane could stop on the runway, even at an approach speed of 168 knots (equal to $V_{REF}30$ + 20 knots, the speed flown in the accident), and an air distance up to about 700 ft longer than the nominal 1,400 ft air distance computed by the OPT.

Administrative Information

Investigator In Charge (IIC):	Bower, Daniel
Additional Participating Persons:	Todd Gentry; FAA Jacob Zeiger; Boeing Armando Martinnez; Miami Air Sam Farmiga ; GE Engines Randy Wallace; Int'l Brotherhood of Teamsters Scott Morrill; U.S. Navy Steven Vincent; Assoc. of Flight Attendants
Original Publish Date:	August 4, 2021
Last Revision Date:	
Investigation Class:	Class 2
Note:	The NTSB traveled to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=99367