Aviation Investigation Final Report

Location:	Memphis, Tennessee	**Accident Number:**	DCA14FA058
Date & Time:	February 5, 2014, 00:22 Local	**Registration:**	N802HK
Aircraft:	Embraer EMB145 - EP	**Aircraft Damage:**	Substantial
Defining Event:	Hard landing	**Injuries:**	53 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

After receiving intermittent localizer indications on the airplane's first approach to the airport, the flight crew, conducted a go-around, and air traffic control cleared the flight for a second approach. The captain indicated that, while the airplane was level at about 2,000 ft on the base leg, the flight entered clouds. The first officer stated that she noted moisture on the windshield wiper and the captain indicated that the wind screen was wet. The cockpit voice recorder (CVR) recorded the captain and first officer briefly discussing ice; however, the airplane's ice protection system, which was set to the automatic mode, did not operate automatically, and the crew did not activate the system manually. The crew did not see the ice light come on and there were no icing messages on the engine indicating and crew alerting system. As the first officer was applying control inputs to adjust for a crosswind, a rapid roll to the right occurred, which resulted in a wing strike and substantial damage to the airplane. About forty minutes after arrival at the gate, an examination of the airplane found an accretion of ice on the leading edge of both wings.

The aircraft performance study, which correlated icing charts with the airplane's flight profile, determined that the airplane spent over 20 minutes at altitudes where icing was probable during both approaches. The study concluded that the right roll was not commanded by the flight crew but likely due to ice buildup. Although the vertical load factor did not indicate that the airplane experienced a full aerodynamic stall, the ice buildup likely created enough flow separation on one wing for it to lose lift during the flare, without affecting the control of the aircraft in a measurable way during the approach.

After the accident, the ice detection and anti-ice systems were tested at the aircraft level with no anomalies identified. The ice detectors were also functionally tested by the manufacturer at the component level with no anomalies identified that could have contributed to the event. A review of FDR data revealed that no failures were recorded for the ice detection system during the accident flight. Additionally, the system operated as expected during a manual preflight test and detected icing conditions during the previous flight. A review of the maintenance records did not reveal any systematic problems with the ice detection system. Therefore, it could not be determined why the ice detection system did not detect the presence of icing conditions even though the airplane accreted ice during the approach. This possibly could have been due to variations in static air temperature that prevented the ice that accumulated on the sensors from reaching the alert threshold or the occurrence of meteorological conditions out of the 14 Code of Federal Regulations Part 25 Appendix C during approach, or a combination of these two factors."

Although the ice detection system did not automatically activate the ice protection system, the CVR recorded a brief discussion during the final approach indicating that the crew was aware that the airplane was picking up "a little bit" of ice. According to the Trans States Airlines EMB145 Airplane Operations Manual (AOM) and Standard Operating Procedures (SOP), even though the airplane is equipped with an ice detector, the crew was responsible for monitoring icing conditions and for manual activation of the ice protection system when necessary.

Therefore, the crew recognized that the airplane was operating in icing conditions and accumulating ice and should have manually activated the ice protection system. It is likely the crew's overreliance on automation for the activation and proper operation of the ice and rain protection system resulted in their failure to adequately monitor the system and respond appropriately when it did not activate automatically.

Although the AOM and SOPs indicated that the crew is responsible for monitoring icing conditions and for manual activation of the ice protection system when necessary, there was no information in Trans States Airlines ground training modules that presented the crew as being responsible for monitoring and activating the ice and rain protection system when no warnings or cautions were received from the EICAS. Additionally, manual ice detection methods for flight crews to use when flying in potential icing conditions were not specifically referenced during ground training. The Trans States Airlines manager of flight standards said that manual selection of the anti-ice system was not emphasized in training like the automatic mode of operation was during flight operations. It is possible that because the manual operation of the airplane's ice protection system was not emphasized during training, the crew may not have recognized the need to perform this task.

Trans States Airlines issued an operations bulletin after the accident that stated interim procedures for crewmembers to follow when operating in potential in-flight icing conditions. The bulletin called for active monitoring of the deicing/anti-icing equipment and, if it did not activate, to accomplish the QRH's Ice Detectors Fail procedures.

Probable Cause and Findings

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

the failure of the flight crew to adequately monitor the system for proper operation and manually activate the system during the flight in icing conditions. Contributing to the accident was the crew's limited training on the manual operation of the anti-ice system and the nonactivation of the automatic ice detection system for reasons that could not be determined.

Findings

Environmental issues	Conducive to structural icing - Awareness of condition
Personnel issues	Monitoring equip/instruments - Flight crew
Aircraft	Airfoil anti-ice, deice - Not used/operated
Organizational issues	Adequacy of policy/proc - Training organization
Aircraft	Ice detection - Unknown/Not determined

Factual Information

History of Flight

Approach-IFR missed approach	Structural icing
Landing-flare/touchdown	Aerodynamic stall/spin
Landing-flare/touchdown	Hard landing (Defining event)

On February 5, 2014, about 0015 central standard time, an Embraer 145EP (EMB-145), N802HK, operating as Trans States Airlines flight 3395, was landing on runway 36R at Memphis International Airport (MEM), Memphis, Tennessee, when it suddenly rolled to the right, and the right wing struck the runway. The 44 passengers and crew onboard were not injured, and the airplane sustained substantial damage. The flight was operating under the provisions of Title 14 *Code of Federal Regulations* Part 121 as a scheduled passenger flight from Houston International Airport (IAH), Houston, Texas, to MEM. Instrument meteorological conditions (IMC) prevailed at the time of the accident.

The accident flight was the flight crew's first flight in the accident airplane that day. The first officer was the pilot flying and the captain was the pilot monitoring (PM). According to the flight crew, the preflight inspection was routine, and the anti-ice system was not tested because it was only required before the airplane's first flight of the day.

The crew indicated that the departure, climb and cruise phases of flight were uneventful. During the descent, the airplane entered a cloud layer about 3,500 ft mean sea level (msl). Air traffic control (ATC) then vectored the flight to a final approach for an instrument landing system (ILS) approach to runway 36L.

According to the crew, before reaching the final approach fix (FAF), they received intermittent localizer course indications on both primary flight displays during the approach. Neither crewmember recalled observing any indications of icing during this approach, and the captain said he noticed no engine indicating and crew alerting system (EICAS) messages for ice.

Inside the FAF, the crew stated the localizer course indications were intermittent again, and they elected to execute a missed approach. According to the aircraft performance study, at 2353, when the go-around was initiated, the airplane was at an altitude of about 2,000 ft. The airplane subsequently climbed to 3,000 ft during the go-around before it returned to and stayed at an altitude of 2,000 ft for about 12 minutes. The study indicated that during the go-around, the airplane spent an additional 19 minutes at an altitude with an increased probability of icing.

The crew notified ATC of the localizer course difficulty they were experiencing on the approach, and the captain requested vectors to the ILS approach to runway 36C. That runway was not available, and ATC cleared the airplane for the ILS approach to 36R.

The captain indicated in a postaccident interview that, while the airplane was level at 2,000 ft, on the base leg to runway 36R, the flight entered clouds. The first officer stated that, near the FAF for the ILS approach to runway 36R, she noticed moisture on the windshield wiper and observed something on the windshield; the captain stated that the wind screen was wet. About 0011, the cockpit voice recorder (CVR) recorded the first officer stating, “are we getting’ ice now,” and the captain replied, “a little bit.” The airplane's ice protection system was in the automatic mode and did not activate nor did the crew manually activate the system. The first officer indicated in a postaccident interview that they did not see the ice light come on and there were no icing messages on the EICAS.

At the FAF, the localizer course signal was uninterrupted, and the airplane's autopilot captured the course. About 0012, the CVR recorded the crew discussing the airplane being configured with landing gear down and 45° of flaps; the captain indicated in a postaccident interview that it was on a stabilized approach at 1,000 and 500 ft. The crew continued the ILS approach, and near the approach minimums (about 400 ft above ground level [agl]), the airplane exited the clouds and the crew observed the landing runway. FDR data indicate that, during the final descent to the runway, the airplane's speed reduced to 130 kts. According to the captain, the first officer announced "landing" and disconnected the autopilot using the control yoke switch when the airplane was about 300 ft above the runway.

After the autopilot was disconnected, the CVR recorded numerous “autopilot” audio messages in the cockpit. The first officer indicated in an interview that she attempted to turn off the audio message but was unable to do so. The CVR recorded the first officer asking, “Why is she not shutting up?” The captain stated that he then held the quick disconnect button for the autopilot to silence it. After the autopilot disengagement, the captain gave a speed warning to the first officer. He stated in an interview that the first officer "got a little slow" (between 5 to 6 kts) during this time and estimated the airplane to be about 100 to 150 ft agl but that the first officer called “correcting” and “got back on speed.” The first officer recalled being slow by about 4 kts.

According to the crew, when the airplane was about 20-40 ft agl, as the first officer was applying control inputs to adjust for a crosswind, a rapid roll to the right occurred. According to the performance study, the airplane began to roll quickly to the right just before 0015, followed by stick shaker activation. One of the airplane's two angle of attack (AOA) sensors reached 15°, and the indicated airspeed was 113 kts; the airplane's maximum roll attitude, which coincided with the stick shaker activation, was 28° right wing down. The airplane's wing struck the runway, and the airplane landed hard on the right side of the runway. The CVR recording and postaccident crew statements indicated that the pilots believed that the sudden roll to the right was caused by a rudder hardover. However, FDR data did not show any evidence of a large rudder surface deflection.

About 40 minutes after the airplane landed, taxied to, and arrived at the gate, the crew observed ice on the wings, horizontal stabilizer, and both engine inlets. The first officer indicated that the airplane was covered in ice, and the captain indicated observing "a lot of ice" on the leading edge of the wings.

Pilot Information

Certificate:	Airline transport	**Age:**	38
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	December 15, 2013
Flight Time:	(Estimated) 6409 hours (Total, all aircraft), 5641 hours (Total, this make and model), 1797 hours (Pilot In Command, all aircraft), 176 hours (Last 90 days, all aircraft), 49 hours (Last 30 days, all aircraft), 3 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Flight instructor	**Age:**	29
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	3-point
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	April 3, 2013
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	(Estimated) 2075 hours (Total, all aircraft), 925 hours (Total, this make and model), 1080 hours (Pilot In Command, all aircraft), 16 hours (Last 90 days, all aircraft), 55 hours (Last 30 days, all aircraft), 7 hours (Last 24 hours, all aircraft)		

All crewmembers were current and qualified in accordance with Federal Aviation Administration (FAA) regulations and Trans States Airlines requirements.

The Captain

The captain was hired by Trans States Airlines in August 2005. A review of the captain's FAA records did not reveal any prior accidents, incidents, or enforcement actions, and a review of his driving records showed no revocations or suspensions. He held an Airline Transport Pilot certificate and had accumulated 6,400 hours of total flight experience, of which about 5,600 was in the Embraer 145.

The captain was based in St. Louis, Missouri, and was on the first day of a 5-day reserve period. The accident flight occurred on his fourth leg of the day. The captain did not recall what time he awoke on February 4 but stated that he had normal sleep and felt rested. He said he departed his home in St Louis about 1115 and checked in for duty about 1300 for a scheduled departure of 1345. On February 3, he was at his residence and did not recall what time he awoke but spent the day at home. He did not recall what time he went to bed but stated that he slept "well." On February 2, he had returned from vacation about 1100 and said he had normal sleep that night.

The First Officer

The first officer was hired by Trans States Airlines in September 2012. A review of FAA records did not reveal any prior accidents, incidents, or enforcement actions, and a review of her driving records showed no revocations or suspensions. She held an Airline Transport Pilot certificate and had accumulated 930 flight hours as second in command in the Embraer 145.

The first officer was also based in St. Louis. The accident flight was her third leg of the day. She indicated that, on February 4, she awoke about 0900 and had slept "well" and that, on February 3, she awoke about 0530 and slept "well." She flew from MEM to Chicago, Chicago to Moline, and Moline to Chicago. She checked into the hotel for a 27-hour layover and went to bed about 2200. On February 2, she commuted in the night prior. She indicated that she awoke about 0400 and had slept well. She flew two flight legs. Her duty day ended at 1100, and she was in bed about 2000.

Aircraft and Owner/Operator Information

Aircraft Make:	Embraer	**Registration:**	N802HK
Model/Series:	EMB145 - EP EP	**Aircraft Category:**	Airplane
Year of Manufacture:	1998	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	145066
Landing Gear Type:	Retractable - Tricycle	**Seats:**	54
Date/Type of Last Inspection:	February 3, 2014 Continuous airworthiness	**Certified Max Gross Wt.:**	43935 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo jet
Airframe Total Time:	34069 Hrs as of last inspection	**Engine Manufacturer:**	Rolls-Royce
ELT:		**Engine Model/Series:**	AE3007A1
Registered Owner:	CIT Leasing Corp	**Rated Power:**	7426 Lbs thrust
Operator:	Trans States Airlines, LLC	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:	Trans States Airlines	**Operator Designator Code:**	RAIA

Ice Detection System

The ice detection system is used to detect and alert the crew about the formation of ice. It is the primary source to automatically activate the airplane's anti-icing systems for the wings and engines. The ice detection system is comprised of two identical ice detection circuits that operate independently during all phases of flight. Each ice detection system circuit has the following components: ice detector, ice detector relay, ice protection overhead panel, circuit breakers, and data acquisition unit.

The ice detector is a one-piece unit including the sensor and processing electronics that detect the presence of ice. When either of the ice detectors detect ice, an advisory message "ICE CONDITION" is shown on the EICAS display, a signal would be sent to the anti-ice system valves to activate them to open, and a signal would be sent to the full authority digital engine control to activate the automated engine icing thrust setting logic to limit the thrust to a minimum acceptable level. The icing signal stays active for 60 seconds. At the same time the icing signal is activated, the ice detector heaters are turned on to deice the detector strut and probe. When the sensing probe is deiced, it is ready to sense ice again. If the icing condition continues and the ice thickness switching level is reached before 60 seconds has passed, the icing signal is continuous. All anti-ice functions operate when one or both detectors detect ice.

The ice detectors are self-monitored through built-in test circuits. A detected failure in either detector would cause a change to the status output signal. This would activate a caution message "ICE DET 1 FAIL" or "ICE DET 2 FAIL" on the EICAS display. The failed unit would not detect ice after an internal failure detection. If a dual ice detector failure condition was present, a caution message "ICE DETECTORS FAIL" would be shown on the EICAS display. If ice detector No. 1 failed, or if both detectors failed simultaneously, the "Ice Detection Fail" parameter on the FDR would also switch to the failed state.

A rotary switch on the ice protection overhead panel allows for a manual test of the ice detectors. Moving the test switch left or right would test the corresponding ice detection system. During the test, the advisory message "ICE CONDITION" is shown on the EICAS display and the caution message "ICE DET 1 FAIL" or "ICE DET 2 FAIL" was shown on the EICAS display. During a manual test of the No. 1 ice detection system, the status of the ice condition output and ice detector fail output would be recorded on the FDR. These parameters would not be recorded on the FDR during a manual test of the No. 2 ice detection system.

The ice detection system would provide the following ice detection messages on the EICAS display:

> ICE CONDITION
> Status: ADVISORY.
> Condition: During ice detector ground test or in-flight detected icing condition
>
> NO ICE-A/ICE ON
> Status: CAUTION.
> Condition: Any bleed air valve is activated when no icing condition is detected. This message is inhibited on the ground. This message will occur if the ice detection override switch is not in the "AUTO" position and ice is not detected during flight.
>
> ICE DET 1 (2) FAIL
> Status: CAUTION.
> Condition: Failure of any single ice detector
>
> ICE DETECTORS FAIL
> Status: CAUTION.
> Condition: Failure of both ice detectors.

Trans States Airlines EMB145 Airplane Operations Manual (AOM), Volume 2, section 2-15, indicated the following:

> *Ice detectors 1 and 2 are respectively installed at the airplane's left and right nose section, to provide icing condition detection. The ice detector was designed to pick up ice quickly. Therefore, in most cases, ice would be detected before it would be noticed by the crew.*
>
> *NOTE: Notwithstanding ice detector monitoring, the crew remains responsible for monitoring icing conditions and for manual activation of the ice protection system if icing conditions are present and the ice detection system is not activating the ice protection system.*

Ice and Rain Protection System

According to the Trans States Airlines EMB145 AOM, Volume 2, Ice and Rain Protection, the airplane's ice protection system heats critical ice accumulation areas through use of either hot bleed air or electrical power. The system is fully automatic and, under icing conditions, activates the entire anti-ice system, except for the windshield heating system. Adequate ice protection for the wings and horizontal stabilizer leading edges and engine inlet lips is obtained by heating these surfaces with bleed air from the engines.

The electrically heated areas are the windshields (must be manually activated), pitot-static tube, AOA sensors, true air temperature (TAT) probes, analog to digital computers, pressurization static ports, lavatory water drains and water service drains. The ice and rain protection system provides signals to the EICAS that displayed appropriate system malfunctions.

In the automatic mode, the system is turned on through activation of the ice detector. The crew could manually activate the system through the OVERRIDE knob on the ice detection panel. Setting the OVERRIDE knob to the ALL position activates the system.

Ice Protection Control Panel

The ice protection control panel was located on the rear corner of the cockpit overhead instrument panel. Trans States Airlines EMB145 AOM, Volume 2, Ice and Rain Protection, pages, 18-20, depicted the switches and indicators available to the flight crew: engine air inlet anti-icing buttons, wing anti-icing button, horizontal stabilizer anti-icing button, sensor heating buttons, windshield heating button, ice detection test knob, and ice detection override knob.

Wing Inspection Lights

The Trans States Airlines EMB145 AOM, Volume 2, External Lighting, page 2, described the wing inspection lights:

> *Two inspection lights, one on each side of the fuselage, provide lighting of the wing leading edge to allow the crew to verify ice formation. The inspection lights are controlled by a switch located on the overhead panel.*

A Trans States Airlines EMB-145 aircrew program designee (APD) stated in an interview that it was hard to see the EMB-145 wings from the cockpit in all conditions. A Trans States Airlines EMB-145 check airman made a similar observation.

An evaluation of an exemplar EMB-145 airplane during hours of darkness revealed that only about the last 3 ft of the leading edge of the wing could be observed from the cockpit from each respective side.

Meteorological Information and Flight Plan

Conditions at Accident Site:	Instrument (IMC)	**Condition of Light:**	Night
Observation Facility, Elevation:	MEM,361 ft msl	**Distance from Accident Site:**	1 Nautical Miles
Observation Time:	11:54 Local	**Direction from Accident Site:**	189°
Lowest Cloud Condition:	Thin Overcast	**Visibility**	1 miles
Lowest Ceiling:	Overcast	**Visibility (RVR):**	
Wind Speed/Gusts:	7 knots / None	**Turbulence Type Forecast/Actual:**	/ None
Wind Direction:	290°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29.92 inches Hg	**Temperature/Dew Point:**	1°C / -1°C
Precipitation and Obscuration:			
Departure Point:	Houston, TX (IAH)	**Type of Flight Plan Filed:**	IFR
Destination:	Memphis, TN (MEM)	**Type of Clearance:**	IFR
Departure Time:	20:22 Local	**Type of Airspace:**	

The MEM weather before the accident reported by the automatic terminal information service at 2354 was wind from 280° at 10 kts, tower visibility 1/2 mile, ceiling overcast at 400 ft agl, temperature 1°C, dew point temperature -1°C, and an altimeter setting of 29.95 inHg. Surface visibility was 8 miles, and the 3-hour precipitation was 0.10 inch.

The METAR provided after the accident at 0054 was wind from 290° at 12 gusting to 19 kts, tower visibility 1/2 mile in mist, ceiling overcast at 400 ft agl, temperature 1°C, dew point temperature -1°C, and an altimeter setting of 29.99 inHg.

At the time of dispatch, there were no National Weather Service advisories for icing conditions over the route of flight. Icing charts from the National Center for Atmospheric Research for 0000 in the region of MEM indicated a probability between 50 to 70% of trace to light icing conditions between 1,000 and 2,000 ft agl. The charts for 0100 depicted light icing conditions below 3,000 ft agl with the probability increasing to 85%.

Airport Information

Airport:	Memphis international Airport MEM	**Runway Surface Type:**	Concrete
Airport Elevation:	341 ft msl	**Runway Surface Condition:**	Unknown
Runway Used:	36R	**IFR Approach:**	ILS
Runway Length/Width:	9000 ft / 150 ft	**VFR Approach/Landing:**	None

FAA flight inspections of the MEM runway 36L localizer and glideslope and runway 36R localizer and glideslope were completed on October 29, 2014, and May 6, 2014, respectively. No anomalies were noted.

Wreckage and Impact Information

Crew Injuries:	3 None	**Aircraft Damage:**	Substantial
Passenger Injuries:	50 None	**Aircraft Fire:**	None
Ground Injuries:		**Aircraft Explosion:**	None
Total Injuries:	53 None	**Latitude, Longitude:**	35.2,-90.056663(est)

A postaccident examination of the airplane revealed damage to the right wing at rib 25R and wing spar 25R. A gusset, the lower skin, a splice plate, and the wing spar at station 145 also sustained damage. The left and right ice detectors were removed from the airplane, examined, and tested. A visual examination of the left ice detector revealed that the connector pins were clean and straight. There was erosion found on the leading edge of the strut. The surface of the trailing edge of the probe had a rough texture and contained traces of a red residue. No other anomalies were noted with the left unit's physical condition. A visual examination of the right ice detector revealed that the pins were clean and straight. The leading edges of the strut and the probe were in good condition. No anomalies were noted with the right unit's physical condition. Both units were then functionally tested and passed all tests, except that the sensing mode frequency on both was slightly lower than the manufacturer's requirement. The manufacturer stated that a lower-than-expected frequency reading would cause the unit to sense ice sooner.

Flight recorders

The airplane was equipped with an FDR and a CVR.

FDR data for the accident flight indicate that the ice detection fail parameter remained in the normal state for the entire flight. The ice condition parameter remained in the no-ice detected state for the entire flight. The FDR records these parameters from the No. 1 ice detection system only.

A review of FDR data from the flight before the accident flight revealed that, before departure, the ice detection fail parameter switched to fail, the ice condition parameter switched from no ice to ice, and the stabilizer anti-ice command and wing anti-ice command switched to on. These parameter changes were consistent with a manual test of the No. 1 ice detection system. During the same flight, shortly after takeoff, the ice detection fail parameter remained in a normal status; the ice condition parameter switched from no ice to ice; and the stabilizer, wing, engine 1, and engine 2 anti-ice commands switched from off to on. These parameter changes are expected for a properly functioning No. 1 ice detection system that has detected icing conditions.

Tests and Research

Performance Study

The NTSB conducted a performance study using FDR, CVR, and radar data. The study indicated that, while on the approach heading, the airplane experienced a 24 knt crosswind at 1,900 ft, dropping to 10 kts on the final portion of the approach. There was no data to support a sudden wind gust to have caused the sudden roll.

The study correlated icing charts from the National Center for Atmospheric Research from the time of the accident with the airplane's altitude and showed that the airplane spent an additional 19 minutes in an altitude region with an increased probability of icing during the go-around. The airplane's automatic ice protection system did not activate, and the airplane's de-ice systems were not on during the approach and landing.

The right roll was not commanded by the pilots as the wheel position did not correspond with the roll. The recorded rudder pedal position was not consistent with the roll being initiated by excessive rudder deflection. During a full aerodynamic stall, the vertical load factor would drop due to the loss of lift, but the vertical load factor stayed between 0.9 and 1.1 g until after the roll event.

Postaccident examination of the airplane revealed ice had built up on the leading edge of the wings, however, the vertical load factor record did not indicate that the airplane experienced a full aerodynamic stall. Ice buildup can cause aerodynamic stall as the ice disrupts airflow across aircraft lift surfaces. Buildup of ice on the leading edge can cause air flow to separate and lift to be lost across the whole or a portion of the wing.

Aerodynamic Simulation

Embraer conducted a simulation of the accident flight using its aerodynamic model of the EMB-145. The goal of the simulation was to quantify the rolling moment needed to match the aileron input and bank angle during the flare portion of the flight. While the simulation did show some differences between the simulation aileron and elevator inputs and the accident flight control surfaces, the discrepancies were small enough that they could have been due to the unavailable exact crosswind and side slip angle data. The simulation did not show a noticeable loss in roll authority or change in flight characteristics during the accident flight. However, ice could cause the airplane to roll by creating enough flow separation on one wing for it to lose lift without the initial ice build-up affecting the control of the airplane in a measurable way.

Trans States Airlines Training

Ice Protection System Training

The EMB-145 ice protection system was covered in a Trans States Airlines ground training module in initial and recurrent training. The training addressed the automated detection and activation of the anti-ice system. There were no training references that presented the crew as being responsible to monitor and potentially activate the system when no warnings or cautions were received from the EICAS. Manual ice detection methods for flight crews to use when flying in potential icing conditions were not referenced during training. The adverse weather ground school training module had several slides that presented potential icing conditions on the ground and the associated crew procedures.

The first officer stated that her training on the anti-icing system was that the system was supposed to let the pilots know when it failed to operate correctly. She said that they were not trained to turn on the system manually but to follow the QRH. She stated that because the crew did not know the anti-ice system did not activate on the accident flight, they did not follow the QRH for an anti-ice system failure. She did not recall the total air temperature (TAT) gauge reading during the final approach. (The QRH checklist for Ice Detector Fail called for the use of visual cues and temperature criteria to determine whether icing conditions existed.

Ice Identification Training

Trans States Airlines provided its EMB145 AOM, Volume 2, as a reference when the wing inspection lights were discussed in training.

A Trans States Airlines APD stated it was easy to tell if the airplane had ice by looking at the pattern on the unheated portion versus the heated portion of the windshield. In addition, a Trans States Airlines check airman said that the windshield wiper and windshield were standard ways to detect icing. The Trans States Airlines chief pilot said he identified icing by looking at the unheated portion of the windshield and the windshield wiper.

Trans States Airlines Procedures

Stabilized Approach Criteria

Trans States Airlines EMB145 Standard Operating Procedures (SOP), section 1, Maneuvers and Procedures Guide, page 40, referenced an airspeed of 127 kts for a landing weight of 41,000 lbs and 45° of flaps and page 39, stated the following:

> *"Stabilized Approach" the approach must be stabilized by 1,000 feet above field elevation when conducting visual and straight in instrument approaches in both IMC and VMC [visual meteorological conditions] weather conditions. During the final approach phase, when operating below stabilized approach height, in both VMC and IMC, on instrument and visual approaches, the following operational parameters must be maintained to be consider the approach stabilized. Sustained deviation from these parameters means the approach has become unstabilized and an immediate missed approach should be initiated. Either pilot may initiate the missed approach utilizing the callout "Go Around.*

? *In-Range and Before Landing checklists complete.*

? *Airplane properly configured; Final flap setting on circling approaches may be delayed as per EMB SOP Sec 1.5.9.*

? *Airspeed in the range Vref -5 knots to Vref +10 knots.*

- *VOR/LOC/FMS course deviation does not exceed one dot deflection.*
- *Glideslope deviation does not exceed one dot deflection.*
- *Descent rate does not deviate +/- 300 feet per minute (fpm) from planned descent rate and is no greater than 1000 fpm, unless specifically briefed.*
- *The airplane is descending along the proper descent path or is able to maintain obstacle clearance.*

Trans States Airlines Unstable Approach Data – General

The Trans States Airlines director of safety stated that there was no data from their Aviation Safety Action Program or FOQA pointing to problems with stabilized approaches. He said their department looked at stabilized approaches, and the trend has been lower this past year. Additionally, a Trans States Airlines Check Airman stated that pilots could go-around and not fear that they would get a call from the chief pilot's office under the company's no-fault go-around policy.

Trans States Airlines EMB145 SOP, section 1, Maneuvers and Procedures Guide, page 38, stated the following:

> *The...PM will callout airplane deviations from the proper approach course and descent profile during any portion of a visual or instrument approach in plain language:*
>
> *Airspeed deviations – the PM will callout sustained deviation +/- 5 knots from the target Vapp speed. The PM will callout airspeed deviations using the call "speed". At approximately 100 feet above touchdown and after the landing is assured, the PM, will call any speed deviation from VREF is the same manner as above.*
>
> *Lateral Course Deviations – The PM will call out LOC deviations of +/- ½ DOT. The word "course" will be called.*

The Trans States Airlines chief pilot and director of safety were not aware of any earlier reports or incidents during which the localizer course was intermittent on final approach to land.

Icing

The Trans States Airlines EMB145 SOP, section 2 - Expanded Flows/Checklist, page 67, indicated the following:

> *After takeoff, the Ice Detection Knob should be set to the AUTO position. The crew was to monitor the weather during the flight.*
>
> *Closely monitor the static air temperature indication so that when moisture is present, a look at the windshield, windshield wiper, engine air inlets, and wing will indicate if ice is accumulating. Notwithstanding installation of the ice detector, the crew remains responsible for monitoring icing conditions and for manual activation of the ice protection system whenever necessary.*

The Trans States Airlines EMB145 AOM, Volume 1, Ice and Rain Protection, page 1, indicated the following:

> *Icing conditions may exist whenever the Static Air Temperature (SAT) on the ground or for takeoff, or ... TAT inflight, is 10°C or below and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet, and ice crystals).*

Autopilot Disconnect

Trans States Airlines EMB145 SOP, section 1, Maneuvers and Procedures Guide, page 80, stated that, upon reaching the decision altitude and having the runway environment in sight, the autopilot will be disconnected and the landing made.

Trans States Airlines EMB145 AOM, Volume 2, Autopilot Disengagement, page 16, stated the following about autopilot disconnect/disengagement:

> *The autopilot is normally disengaged through the Autopilot Engage/Disengage button or through the quick disconnect button on the control wheel.*
>
> *A voice message AUTOPILOT is generated when the autopilot is disengaged.*

The AOM indicated that the voice message occurs at any altitude in case of intentional disengagement or due to an autopilot failure and may be canceled below 2,500 ft radio altitude with a valid radio altimeter signal or with an invalid radio signal by pressing the autopilot quick disconnect button twice.

Trans States Airlines EMB145 AOM, Volume 2, Autopilot, Controls and Indicators, page 8, depicted the control wheel and associated switches available to the crew and offered the following information:

> *2 - QUICK DISCONNECT BUTTON*
>
> *- Provides the means to disengage autopilot and yaw damper.*
>
> *- The pilot's and copilot's buttons are interconnected to allow autopilot cancellation from either seat.*
>
> *- ... if the autopilot is disengaged and the button is pressed, the voice message AUTOPILOT will be canceled in 2 seconds.*

According to the crew, during the accident flight, the autopilot audio, which announced the autopilot was disconnected, remained on for several seconds. The captain said this audio annoyed the first officer and he held down the autopilot quick disconnect button to silence it. The captain further stated that the first officer apparently did not hold down the autopilot disconnect button long enough to get the aural warning to stop. The first officer said she could not get the autopilot audio to silence when she used the yoke switch to disconnect it and asked the captain to turn it off.

Interviews with a Trans States Airlines EMB145 APD revealed that the autopilot disconnect issue where the audio remained on for an extended period of time was a distraction for new hires and usually was corrected by the time they completed training. He said that new pilots usually tap the disconnect switch too quickly rather than press and hold the switch between activations. The Trans States Airlines manager of flight standards indicated that he has seen the autopilot disconnect audio distraction with new crews in the simulator.

Ice Protection Check

According to the Trans States Airlines EMB145 SOP, section 2, Expanded Flows/Checklists,the ice protection test was a first-flight-of-the-day-only check.

Airplane Icing Limitations

Trans States Airlines EMB145 SOP, section 2, Expanded Flows/Checklists, page 67 stated the following:

> *After Takeoff:*
>
> *The Ice Detection Override Knob should be set to the AUTO position. Monitor weather conditions for an encounter of ice for the remainder of the flight. Closely monitor the static air temperature indication so that when moisture is present, a look at the windshield, windshield wiper, engine air inlets, and wing will indicate if ice is accumulating. Notwithstanding installation of the ice detector, the crew remains responsible for monitoring icing conditions and for manual activation of the ice protection system whenever necessary.*

Trans States Airlines EMB145 SOP, section 2, Expanded Flows/Checklists, page 70, stated the following:

> *General Remarks when Flying in Icing Conditions: (temp range) AOM*
>
> *- Continuously monitor engine parameters, airplane pitch attitude and airspeed. Be careful for any mis-trim condition that may be masked by the autopilot. Keep the airplane trimmed all the time.*
>
> *- Monitor the anti-ice systems for proper operation. Apply the associated abnormal procedure in case of a system failure. If the failure persists, exit and avoid icing conditions. Advise ATC that you are requesting the change due to icing conditions.*
>
> *- Do not hesitate to leave severe icing conditions, even with anti-ice system operating properly.*

The Trans States Airlines EMB Airplane QRH checklist for Wing Anti-Icing Failure called for the ice detection override knob to be selected to the "ALL" position. It also stated that if in icing conditions or if there is any uncertainty as to whether the wing surfaces are clear of ice before the approach and landing, to proceed to a flaps 22° landing configuration and increase V_{ref} for 45° of flaps airspeed by 30 kts.

The Trans States Airlines EMB Airplane QRH checklist for Ice Detector Fail stated the following:

> *EICAS CAUTION: ICE DET 1 (2) FAIL or ICE DETECTORS FAIL Use visual cues (ice accretion on windshield and windshield wipers) and temperature criteria to determine whether icing conditions exist.*
>
> *When flying in icing conditions:*
>
> *Ice Detection Override Knob ....ALL*
>
> *After positively exiting icing conditions:*
>
> *Ice Detection Override Knob .... AUTO*

__NOTE:__ - Icing conditions may exist in-flight when...TAT is 10°C or below and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet, and ice crystals).

The Trans States Airlines EMB Airplane QRH checklist for Anti-icing Inoperative in Icing Conditions stated that, in flight, the flight crew should manually operate the anti-ice system by selecting the ice detection override knob to "ALL."

Additional Information

Postaccident Actions

Trans States Airlines

Trans States Airlines issued an urgent safety bulletin on February 7, 2014, titled "Automatic Anti-Ice Monitoring." The bulletin discussed an incident under investigation and advised flight crews to be vigilant about monitoring deicing/anti-icing equipment when operating in icing conditions. The bulletin also "strongly encouraged" flight crews to reference minimum equipment list (MEL) 30-80-00 (Ice Detectors Inoperative) when operating in icing conditions and the crew does not observe the appropriate "open" indications on the push buttons (deice/anti-ice equipment is active).

Trans States Airlines issued Operations Bulletin 01-2014 on February 19, 2014, that superseded the urgent safety bulletin. The bulletin issued interim procedures for flight crewmembers to follow when operating in icing conditions above 1,500 ft agl. The bulletin called for active monitoring of the deicing/anti-icing equipment and, in the event it does not activate, to accomplish the QRH Ice Detectors Fail procedures.

Administrative Information

Investigator In Charge (IIC):	Lovell, John
Additional Participating Persons:	Daniel Marimoto; Embraerb
Original Publish Date:	February 24, 2021
Last Revision Date:	
Investigation Class:	Class 3
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=88786

The National Transportation Safety Board (NTSB) is an independent federal agency charged by Congress with investigating every civil aviation accident in the United States and significant events in other modes of transportation—railroad, transit, highway, marine, pipeline, and commercial space. We determine the probable causes of the accidents and events we investigate, and issue safety recommendations aimed at preventing future occurrences. In addition, we conduct transportation safety research studies and offer information and other assistance to family members and survivors for each accident or event we investigate. We also serve as the appellate authority for enforcement actions involving aviation and mariner certificates issued by the Federal Aviation Administration (FAA) and US Coast Guard, and we adjudicate appeals of civil penalty actions taken by the FAA.

The NTSB does not assign fault or blame for an accident or incident; rather, as specified by NTSB regulation, "accident/incident investigations are fact-finding proceedings with no formal issues and no adverse parties … and are not conducted for the purpose of determining the rights or liabilities of any person" (Title 49 *Code of Federal Regulations* section 831.4). Assignment of fault or legal liability is not relevant to the NTSB's statutory mission to improve transportation safety by investigating accidents and incidents and issuing safety recommendations. In addition, statutory language prohibits the admission into evidence or use of any part of an NTSB report related to an accident in a civil action for damages resulting from a matter mentioned in the report (Title 49 *United States Code* section 1154(b)). A factual report that may be admissible under 49 *United States Code* section 1154(b) is available here.