Crash During Approach to Landing
Circuit City Stores, Inc.
Cessna Citation 560, N500AT
Pueblo, Colorado
February 16, 2005

ACCIDENT REPORT

NTSB/AAR-07/02
PB2007-910403

National
Transportation
Safety Board

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Aircraft Accident Report

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National Transportation Safety Board
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Abstract: This report explains the accident involving a Cessna Citation 560, N500AT, operated by Martinair, Inc., for Circuit City Stores, Inc., which crashed about 4 nautical miles east of Pueblo Memorial Airport, Pueblo, Colorado, while on an instrument landing system approach to runway 26R. The safety issues discussed in this report include inadequate training on operations in icing conditions, inadequate deice boot system operational guidance, the need for automatic deice boot systems, inadequate certification requirements for flight into icing conditions, and inadequate stall warning margins in icing conditions.

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Abbreviations

agl	above ground level
AC	advisory circular
AD	airworthiness directive
AFM	airplane flight manual
AIRMET	airmen's meteorological information
AOA	angle-of-attack
ARAC	aviation rulemaking advisory committee
ARTCC	air route traffic control center
ASOS	automated surface observing system
ASR-7	airport surveillance radar-7
ATC	air traffic control
ATIS	automatic terminal information service
ATP	airline transport pilot
BFU	German Federal Bureau of Accidents Investigation
C	Celsius
CAM	cockpit area microphone
CFR	*Code of Federal Regulations*
CG	center of gravity
COU	Columbia Regional Airport
CVR	cockpit voice recorder
EGPWS	enhanced ground proximity warning system
FAA	Federal Aviation Administration
fpm	feet per minute
FSS	flight service station
Hg	mercury
ILS	instrument landing system

IMC	instrument meteorological conditions
IPHWG	Ice Protection Harmonization Working Group
METAR	meteorological aerodrome report
mm	millimeter
msl	mean sea level
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
nm	nautical mile
NPRM	notice of proposed rulemaking
NWS	National Weather Service
PIREP	pilot report
PUB	Pueblo Memorial Airport
PWC	Pratt & Whitney Canada
SB	service bulletin
SLD	supercooled large droplet
sm	statute mile
TCAS	traffic alert and collision avoidance system
UTC	universal coordinated time

Executive Summary

On February 16, 2005, about 0913 mountain standard time, a Cessna Citation 560, N500AT, operated by Martinair, Inc., for Circuit City Stores, Inc., crashed about 4 nautical miles east of Pueblo Memorial Airport, Pueblo, Colorado, while on an instrument landing system approach to runway 26R. The two pilots and six passengers on board were killed, and the airplane was destroyed by impact forces and postcrash fire. The flight was operating under the provisions of 14 *Code of Federal Regulations* Part 91 on an instrument flight rules flight plan. Instrument meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to effectively monitor and maintain airspeed and comply with procedures for deice boot activation on the approach, which caused an aerodynamic stall from which they did not recover. Contributing to the accident was the Federal Aviation Administration's failure to establish adequate certification requirements for flight into icing conditions, which led to the inadequate stall warning margin provided by the airplane's stall warning system.

The safety issues discussed in this report include inadequate training on operations in icing conditions, inadequate deice boot system operational guidance, the need for automatic deice boot systems, inadequate certification requirements for flight into icing conditions, and inadequate stall warning margins in icing conditions. Safety recommendations concerning these issues are addressed to the Federal Aviation Administration.

1. Factual Information

1.1 History of Flight

On February 16, 2005, about 0913 mountain standard time,[1] a Cessna Citation 560, N500AT, operated by Martinair, Inc., for Circuit City Stores, Inc.,[2] crashed about 4 nautical miles (nm) east of Pueblo Memorial Airport (PUB), Pueblo, Colorado, while on an instrument landing system (ILS) approach to runway 26R. The two pilots and six passengers on board were killed, and the airplane was destroyed by impact forces and postcrash fire. The flight was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 91 on an instrument flight rules flight plan. Instrument meteorological conditions (IMC) prevailed at the time of the accident.

The accident flight and another Circuit City Stores Cessna 560 (N500FK, referred to in this report as the "sister ship") were scheduled to transport Circuit City Stores employees from Richmond International Airport, Richmond, Virginia, to John Wayne Airport, Santa Ana, California, with scheduled fuel stops at Columbia Regional Airport (COU), Columbia, Missouri, and PUB. The accident flight departed Richmond about 0600 eastern standard time. The flight arrived at COU about 0736 central standard time and departed for PUB about 30 minutes later.

At 0847:48, while descending through about flight level 370,[3] the cockpit voice recorder (CVR)[4] recorded the Denver Air Route Traffic Control Center (ARTCC) instructing the flight crew to descend to and maintain 13,000 feet. About 0851, the CVR recorded the flight crew start discussing the icing conditions. Specifically, at 0850:40, the captain stated, "I'm gonna heat 'em up."[5] About 4 minutes later, the captain stated that he turned the windshield heat on, and he then asked the first officer to let him know if he saw any ice on the wing. The first officer replied that he saw ice "building a little bit right on

[1] Unless otherwise indicated, all times in this report are mountain standard time based on a 24-hour clock.

[2] Circuit City Stores owned the airplane. Martinair, an aircraft management and charter company, operated and managed the accident airplane for Circuit City Stores. See section 1.17 for more information.

[3] Flight level 370 is an altitude of 37,000 feet mean sea level (msl) based on an altimeter setting of 29.92 inches of mercury (Hg). Unless otherwise indicated, all altitudes referenced in this report are reported as height above msl.

[4] Correlation of the CVR recording to mountain standard time was established using times from the air traffic control (ATC) transcript prepared by the Federal Aviation Administration and PUB airport surveillance radar-7 radar. The time alignment of the CVR recording and radar revealed that the CVR clock was about 10 seconds ahead of the radar clock. As a result, the CVR times are presented with a 10-second offset to provide a consistent time base between the CVR and ATC sources. The airplane was not equipped with a flight data recorder.

[5] The captain's comment most likely refers to the activation of the engine anti-ice system, which heats the engine inlets and the inboard wing leading edges. For more information about the airplane's anti-ice and deice systems and guidance on the usage of these systems, see sections 1.6.3 and 1.17.1.3, respectively.

the [wing] leading edge…it's not the real white ice like we had yesterday. It's more of a grayish." The first officer then stated, "there's a real thin line back there." About 2 minutes later, the captain stated that it did not look like the airplane had accumulated any more ice.

At 0858:20, as the airplane was descending through about 18,000 feet, the first officer suggested that the captain cycle the deice boots. After cycling the deice boots, the captain stated, "might've gotten rid of a little but not much." At 0859:29, the first officer stated that the V_{ref} was 96 knots.[6] About 3 1/2 minutes later, the captain told the first officer to "leave the heats on," and the first officer replied, "okay. Got everything nice and warmed up."

At 0905:50, the first officer contacted PUB approach control and stated, "Pueblo approach…thirteen thousand with [automatic terminal information service] Juliet."[7] The PUB local controller instructed the flight crew to fly heading 240° for the ILS runway 26R final approach course and to descend to and maintain 7,000 feet. The first officer asked, "did you say two six right now?" The controller confirmed that runway 26R was in use. The controller also reported that a regional jet was in a holding pattern over PUB at 9,000 feet and asked the pilots to report when they had the airplane in sight.[8] The first officer then told the captain that the controller had changed the landing runway from 8L to 26R.

At 0907:36, the PUB local controller asked the pilots if they had the airplane in sight, and the first officer stated that he did not. The controller replied, "give me a best rate of descent through niner thousand or maintain one zero thousand. I'll just turn you." The first officer stated that they would descend to 7,000 feet. At 0908:25, the first officer reported to the controller that the flight was in IMC at an altitude of about 9,400 feet. The controller then instructed the flight to turn left to a heading of 170°. At 0908:55, the controller instructed the flight crew to turn right to a heading of 290° to intercept the localizer inbound. He then instructed the flight crew to maintain 7,000 feet and cleared the flight for the approach.

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[6] V_{ref} is the landing reference airspeed with full flaps and landing gear down. In accordance with company guidance, if any amount of residual ice (that is, ice that remains on the deice surface after the deice boots have been cycled) is present, the V_{ref} should be increased by 8 knots, which would have resulted in a V_{ref} of 104 knots instead of the 96 knots reported by the first officer. For more information about guidance on operations in icing conditions, see section 1.17.1.2.

[7] Automatic terminal information service (ATIS) information "Juliet," which broadcast the 0753 weather, reported the following: wind 060° at 6 knots, visibility 10 statute miles, measured ceiling 1,400 feet overcast, temperature -3° Celsius (C), dew point -5° C, altimeter 30.16 inches of Hg. ATIS information "Juliet" also indicated that the landing runway in use was 8L. Altitudes referenced in this report from surface weather observations and terminal aerodrome forecasts are reported as height above ground level (agl). See section 1.7 for more meteorological information.

[8] During postaccident interviews, the captain of the holding airplane stated that he had initially requested and received a holding pattern altitude of 8,000 feet. He stated that, although he was informed by ATC that icing conditions existed at that altitude, he decided to descend to 8,000 feet. As the airplane descended toward 8,000 feet into IMC, it began accumulating ice. He stated that he turned on the airplane's wing anti-ice and immediately requested a climb to 9,000 feet to exit the icing conditions. He stated that, at 9,000 feet, the airplane was above the cloud layer and mostly in the clear. He characterized the icing as rime ice but did not know its accumulation rate or severity.

At 0909:19, the first officer stated, "you got a little different ice on there now. It's clear." The captain replied, "yeah," and he then instructed the first officer to "open up those valves all the way."[9] The first officer replied, "all right, will do." At 0909:41, the PUB local controller provided the flight crew with the current weather, which indicated the following: cloud ceilings broken at 900 feet and overcast at 1,400 feet, visibility 6 statute miles (sm) in mist, temperature -3° Celsius (C), dew point -4° C, wind 070° at 7 knots, and altimeter 30.16 inches of mercury (Hg).

At 0910:22, the first officer stated, "ignition is on with the anti-ice, now it's on for sure. Glideslope is alive." At 0911:10, the captain stated, "[landing] gear's down." The PUB local controller cleared the flight to land on runway 26R and instructed the flight crew to maintain its present heading and altitude until established on the ILS localizer. At 0911:45, the CVR recorded the captain stating, "speed brakes coming back out." The first officer replied, "okay…there's your glideslope intercept." The captain then called for full flaps. The first officer responded, "full flaps, here we go…full selected and indicated." At 0912:00, the first officer briefed the missed approach. Four seconds later, he stated, "you are plus twenty five,"[10] and the captain replied, "slowing." At 0912:37, the first officer stated, "I don't know if you want to run your ice a little bit. You got the V_{ref} there."

Airplane performance calculations show that, about 0912:40, immediately after passing through about 6,100 feet,[11] the airplane experienced an upset and the onset of a large roll to the left concurrent with a rapid decrease in pitch. The CVR recorded a short tone concurrent with the beginning of the upset. The frequency and the duration of the tone were consistent with the autopilot disconnect horn.[12] At 0912:46, the CVR recorded the enhanced ground proximity warning system (EGPWS) "bank angle" aural warning alert.[13] The last radar return was received at 0912:54 while the airplane was at an altitude of about 4,922 feet. One second later, the CVR stopped recording. According to the Federal Aviation Administration (FAA) air traffic control (ATC) transcript, at 0912:57, the PUB local controller issued an altitude alert to the accident flight, stating, "zero alpha tango altitude alert altitude indicates four thousand niner hundred over."

1.1.1 The Sister Ship History of Flight

During postaccident interviews, the sister ship captain indicated that, according to the airplane's traffic alert and collision avoidance system (TCAS), the accident airplane was about 19 nm ahead of the sister ship en route to PUB. The flight crewmembers reported that, during the descent to PUB, the airplane was accreting rime ice;[14] however,

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[9] The captain was most likely referring to the windshield anti-ice bleed air valves, which control the volume of engine bleed air to the windshield. The three-position (LOW, OFF, and HIGH) windshield bleed air switch controls the temperature of the air to the windshield.

[10] The first officer's comment "plus twenty five" refers to the V_{ref} plus 25 knots.

[11] The airplane was at an altitude of about 1,500 feet above ground level at the time of the upset.

[12] The autopilot can be manually disconnected by the pilot or it can be automatically disconnected if certain conditions occur, such as a roll angle of more than 40° or a roll rate of more than 20° per second.

[13] Analysis of the EGPWS data indicated that the bank angle at the time of the alert was about 50°.

they stated that no visible precipitation was present. The first officer estimated that the ice was less than 1/2-inch thick and stated that the deice boots effectively shed the ice. He stated that there was no ice on the heated inboard wing leading edge or on the top of the wing. The first officer stated that a little ice had formed on the windshield and that he selected the HIGH heat setting to deice and defog the windshield. The captain stated that they kept the airspeed up on the approach because of the icing conditions.[15] The captain stated that they broke out of the clouds about 1,200 to 1,400 feet and that the visibility was about 6 nm with no precipitation.

The captain stated that he heard the PUB controller clear the accident airplane to land and the flight crew acknowledge the clearance. He stated that, shortly afterward, he heard the controller issue a low-altitude warning of about 4,900 feet. He stated that the controller called for the accident flight three or four times but that the flight crew did not acknowledge. He stated that he then looked at the TCAS and saw that the accident airplane was no longer displayed. The sister ship landed on runway 8L about 0926 without incident. The flight crew and passengers reported that they observed some ice on the airplane after landing.

A review of the sister ship's CVR revealed that the pilots conducted several procedures to minimize any icing problems, including cycling the wing deice boots five times, turning the windshield heat to the HIGH position, using only approach flaps until close to the ground, and keeping the engine power and speed as high as possible until clear of the clouds and landing was assured.

1.2 Injuries to Persons

Table 1. Injury chart.

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	2	0	6	0	8
Serious	0	0	0	0	0
Minor	0	0	0	0	0
None	0	0	0	0	0
Total	2	0	6	0	8

[14] Rime ice is an opaque, granular, and rough deposit of ice that usually forms on the airplane's surfaces, including, in part, the wing leading edges, the horizontal stabilizers, and the engine inlets.

[15] Airplane performance calculations revealed that the sister ship's airspeed was more than 160 knots as the airplane descended through about 6,200 feet and that the airplane maintained an airspeed of about 120 knots until it was about 200 feet above airport elevation. Calculations revealed that the accident airplane's airspeed was about 98 knots as it descended through about 6,200 feet.

1.3 Damage to Aircraft

The airplane was destroyed by impact forces and a postcrash fire.

1.4 Other Damage

No other damage resulted from this accident.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 53, was hired by Martinair on February 1, 2002. He held a multiengine airline transport pilot (ATP) certificate, issued October 11, 1996, with type ratings in Beechcraft 300 and 1900, Cessna 500, and Dassault Falcon DA-10 series airplanes. The captain held a first-class FAA airman medical certificate, dated February 7, 2005, with the limitations that he "must wear lenses for distance" and "possess glasses for near vision."

According to the captain's employment application for Martinair, from July 1989 to January 2001, he worked as a pilot in Cessna 560 airplanes at Southern States. From January 2001 to February 2002, he worked as a pilot in Cessna Citation Ultra airplanes at Chesapeake Corporation. Martinair records indicated that the captain had accumulated 8,577 total flight hours, including 2,735 hours in Cessna Citation airplanes, 1,500 hours of which were as pilot-in-command. He had flown about 113, 39, 12, and 3 hours in the 90, 30, and 7 days and 24 hours, respectively, before the accident. The captain's last Cessna 500 series proficiency check occurred on November 1, 2004; his last recurrent ground training occurred on November 30, 2004; and his last line check occurred on January 4, 2005. A search of FAA records revealed no accident or incident history, enforcement action, or pilot certificate or rating failure or retest history. A search of the National Driver Register found no record of driver's license suspension or revocation.

According to the captain's wife, he slept his normal sleep schedule[16] at home in Richmond for several nights before February 15, 2005. On February 14, he flew a roundtrip to South Bend, Indiana, during the day (with the accident first officer). She stated that, on February 15, he left home by early afternoon, returned about 1500, and was awake in bed when she returned about 2030 to 2100. She stated that, on the morning of the accident, he awoke early; however, she did not know what time he departed for the airport.

[16] According to the captain's wife, he normally went to sleep about 2200 to 2300 and awoke by 0700 when he did not have to work. She stated that the captain sometimes had difficulty sleeping.

1.5.2 The First Officer

The first officer, age 42, was hired by Martinair in November 2004. He held a multiengine ATP certificate, issued March 3, 2004, with a type rating in Cessna 500 series airplanes. The first officer held a first-class FAA airman medical certificate, dated August 2, 2004, with no limitations.

According to the first officer's employment application for Martinair, from April 2002 to November 2004, he worked as a pilot in Cessna Citation airplanes for Commonwealth Aviation Services, Inc. Martinair records indicated that the first officer had accumulated 2,614 total flight hours, including 1,397 hours in Cessna Citation series airplanes, 322 hours of which were as pilot-in-command. He had flown about 127, 37, 11, and 3 hours in the 90, 30, and 7 days and 24 hours, respectively, before the accident. The first officer's last Cessna Citation 500 series proficiency check and line check occurred on February 10, 2005, and his last recurrent ground training occurred on December 30, 2004. A search of FAA records revealed no accident or incident history, enforcement action, or pilot certificate or rating failure or retest history. A search of the National Driver Register found no record of driver's license suspension or revocation.

According to the first officer's wife, he slept his normal sleep schedule[17] at home in Richmond for several nights before February 15, 2005. She stated that, on February 14, he was still in bed when she left the house about 0730; he flew a roundtrip to South Bend that afternoon; and he went to bed about 2200 to 2300. On February 15, he flew another roundtrip to South Bend, and he went to bed about 2100 to 2130. On the morning of the accident, he awoke about 0300 and left the house about 0345 to 0400.

1.6 Aircraft Information

1.6.1 General Aircraft Information

The accident airplane, serial number 0146, was manufactured by Cessna Aircraft Company on October 22, 1991, and was certified to 14 CFR Part 25 standards. At the time of the accident, the airplane had accumulated about 3,658 total flight hours. The airplane was equipped with two Pratt & Whitney Canada (PWC) JT15D-5A turbofan engines. The time since new for both engines was about 3,585 hours, and the time since overhaul for both engines was about 114 hours.

Martinair provided National Transportation Safety Board investigators with estimated weight and balance information for the accident flight.[18] According to these estimates, the accident airplane's landing weight was about 13,040 pounds, including

[17] According to the first officer's wife, he normally went to sleep about 2200 and awoke by 0800 when he did not have to work.

[18] The actual weight and balance information for the accident airplane was not found. Title 14 CFR Part 91 regulations do not require pilots to leave a manifest at the departure airport.

2,000 pounds of fuel, 1,100 pounds of passenger weight, and 180 pounds of baggage, which was within the landing weight limit of 15,200 pounds. The estimates showed that the airplane's landing center of gravity (CG) was 16.8 percent mean aerodynamic chord, which was within the landing CG limits of 16 to 28 percent.

The airplane was equipped with speedbrakes, which are small panels that extend from the upper and lower surfaces of each wing to increase descent rates.[19] After the accident, the left speedbrakes remained attached to the wing and were in the fully extended position. The right speedbrakes remained attached to the wing but were in an intermediate position. However, the speedbrake panels and hydraulic actuators on both wings were able to move freely.

1.6.2 Stall Warning System

The accident airplane was equipped with a stall warning and angle-of-attack (AOA) system, which consisted of an AOA vane, indicator, indexer, and computer, and a stickshaker mounted on the forward side of the pilot's control column. The AOA vane, which is located on the forward right side of the fuselage, streamlines with the relative airflow and transmits the sensed angle to the AOA system. Inputs from the AOA system are transmitted to the stickshaker, which has an electric motor with rotating weights that induce vibration to the control columns, providing a tactile warning to pilots of an impending stall. The stickshaker is designed to alert pilots of an impending stall about 7 percent above the actual stall speed when the airplane's surfaces are not contaminated by ice.[20]

According to the Cessna Model 560 Citation V Operating Manual, the airplane was equipped with an upgraded, dual-mode AOA computer, which incorporated normal and ice modes. The ice mode is activated when either engine anti-ice switch is selected ON. In normal mode, stickshaker activation is referenced to standard airplane stall speeds, and, in ice mode, stickshaker activation is referenced to standard airplane stall speeds plus 5 knots to account for the increase in stall speed caused by airframe ice accumulation.[21]

According to the Cessna Model 560 Citation V Airplane Flight Manual (AFM), the accident airplane's stall speed, with no ice on the wings and assuming an airplane weight of about 13,300 pounds and full flaps selected, should have been about 76 knots. The AFM states that, with ice on the wings, the stall speed increases by 5 knots; therefore,

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[19] The speedbrakes are electrically controlled and hydraulically actuated by a switch located on the throttle quadrant in the cockpit and may be selected to the fully extended or fully retracted (stowed) position. The speedbrakes are held in the stowed position by mechanical catches. A light illuminates in the cockpit when the speedbrakes are in transition and when they are fully extended.

[20] According to Advisory Circular 25-7, "Flight Test Guide for Certification for Transport Category Airplanes," "the stall warning should normally begin at a speed not less than 7 percent above the stall speed."

[21] During flight tests of Cessna 560 series airplanes, which were conducted by the FAA in 1996, it was determined that the stall speed increased from 3 to 5 knots in icing conditions. In early 1999, Cessna began installing stall warning systems that incorporated the ice mode. For more information about these tests and subsequent FAA and Cessna actions, see section 1.18.1.

the stall speed for the accident airplane should have been about 81 knots. As noted, the stickshaker is designed to alert pilots of an impending stall about 7 percent above the actual stall speed; therefore, the stickshaker should have activated at about 86 knots.

The Cessna Model 560 Citation V AFM states that the stall warning system must be operable and a preflight check must be performed before takeoff. The sister ship captain, who flew the accident airplane the day before the accident, reported no pre- or in-flight stall warning system problems. Further, no discrepancies were noted during the last scheduled maintenance inspection of the stall warning system, which was completed on December 1, 2003.

Postaccident examinations of the stall warning system components revealed that the AOA computer and vane electrical heating element exhibited heat and fire damage, which precluded functional checks. The AOA vane was able to move freely. The stall warning stickshaker and the vane heating elements were found to be functional during postaccident tests.

1.6.3 Anti-Ice and Deice Systems

The Cessna 560 is certified to operate in known icing conditions and is equipped with anti-ice and deice systems to prevent ice accumulation on various exterior areas of the airplane.[22] The engine anti-ice system uses engine bleed air to heat the engine inlets and the inboard wing leading edges, and the windshield anti-ice system uses engine bleed air to heat the windshield. The pitot static anti-ice system uses electrical heating elements to prevent ice buildup on the pitot tubes, static ports, and AOA vane. The anti-ice systems are activated by switches in the cockpit. Activation of the engine and windshield anti-ice systems and failures of the engine and pitot static anti-ice systems are annunciated by lights in the cockpit.

The surface deice system consists of pneumatic boots on the outboard wing leading edges and the horizontal stabilizer. The deice system is typically activated by selecting the surface deice switch to the AUTO position. During the 18-second automatic deice boot cycle,[23] pneumatic pressure from engine bleed air inflates the lower boots on the wing leading edges and the boot on the left horizontal stabilizer, then these boots completely deflate. The upper boots on the wing leading edges and the boot on the right horizontal stabilizer then inflate and deflate. After deflation of the upper deice boots, the cycle is terminated. Deice boot system activation is annunciated by lights in the cockpit.

The deice boot system can also be operated manually by holding the deice surface control switch in the MANUAL position. As long as the control switch is held in the MANUAL position, all of the deice boots will inflate simultaneously and deflate when the

[22] According to the Cessna Model 560 Citation V AFM, the airplane's anti-ice and deice systems were not designed to protect against freezing rain or severe conditions of mixed or clear ice.

[23] The AUTO mode automatically cycles the deice boots through one 18-second deice boot cycle. However, to activate another 18-second cycle, the pilot would have to move the surface deice switch to the AUTO position again.

switch is released. If the switch is placed and held in the MANUAL position during automatic cycle operation, the MANUAL will override the AUTO function, all of the deice boots will simultaneously inflate, and the automatic cycle will time out.

CVR information indicated that the captain activated the deice boots and that the boots had removed some of the ice. Further, no discrepancies were noted during the last scheduled maintenance inspections of the anti-ice and deice systems, which were completed on December 1, 2003.

After the accident, the engine anti-ice switches were found fractured, and their positions could not be determined. The windshield bleed air switches were missing. The left and right windshield bleed air valve positions could not be determined because the cables had been pulled out of both control mechanisms. The pitot static heat switch was found in the ON position. The surface deice switch was found spring-loaded to the neutral position. The deice control valves were found separated from the wreckage and damaged. On-scene disassembly revealed that the deice control valves were free of obstruction, and a functional test showed that the valves functioned properly.

The left- and right-wing leading edge deice boots were severely damaged by impact and postcrash fire. The left and right horizontal stabilizer deice boots were damaged. The deice boot air supply lines from the tail section to the wings were damaged and/or consumed by fire.

1.7 Meteorological Information

1.7.1 National Weather Service Information

A terminal aerodrome forecast prepared for PUB by the National Weather Service (NWS), which was issued at 0442 and was valid at the time of the accident, stated, in part, the following:

> winds 080° at 8 knots, visibility greater than 6 miles, skies scattered at 2,000 feet and overcast at 2,500 feet. Temporary condition between 1200Z[24] to 1600Z, visibility 3 miles in light freezing drizzle, mist, skies overcast at 1,000 feet. From 1600Z, winds 070° at 8 knots, visibility greater than 6 miles, skies scattered at 1,000 feet and overcast at 2,500 feet.

The NWS also issued several winter weather advisories on the morning of the accident.[25] The advisories issued at 0750 and 0934 warned that freezing drizzle existed along the accident flightpath through the midmorning hours.

[24] Weather forecasts are transmitted in coordinated universal time (UTC). The "Z" designation that follows the time in the weather observation stands for Zulu, which indicates UTC time. Mountain standard time is 7 hours behind UTC time.

[25] Although winter weather advisories are not aviation-related products, they provide additional information about atmospheric conditions.

About 0745, the NWS issued AIRMET [airmen's meteorological information] Zulu, which covered the Pueblo area and was valid at the time of the accident. AIRMET Zulu warned of "occasional moderate rime or mixed icing in clouds and precipitation between freezing level and 22,000 feet, with the freezing level between the surface and 8,000 feet." About 0830, the NWS issued AIRMET Sierra, which also covered the Pueblo area and was valid at the time of the accident. AIRMET Sierra warned of "occasional [cloud] ceilings below 1,000 feet and/or visibilities below 3 statute miles." AIRMET Sierra also warned of obscured mountains caused by precipitation, clouds, mist, and/or fog.

Base reflectivity image data were derived from the Weather Surveillance Radar-1988 Doppler system, which is located 15 nm northeast of the accident site. Data from the system's 0911 atmospheric profile showed weak reflectivity values near the accident site, consistent with the presence of freezing drizzle atmospheric conditions. Geostationary Operational Environmental Satellite 10 data from the National Oceanic and Atmospheric Administration satellite indicated cloud top temperatures from -19° to -11° C and the presence of cloud layers in the area surrounding the airplane's flightpath.

The 0500 upper air sounding (that is, a vertical profile of atmospheric conditions) from Denver, Colorado (about 92 nm northeast of the site), showed temperatures below freezing from the surface to 30,000 feet. The sounding showed no layers in the atmosphere with temperatures above freezing.

1.7.2 Airport Weather Information

Weather observations at PUB are made by an automated surface observing system (ASOS) located about 3 nm west of the accident site. The ASOS records continuous information on wind speed and direction, cloud cover, temperature, precipitation, and visibility and transmits an official meteorological aerodrome report (known as a METAR) each hour. The 0853 METAR indicated the following:

> wind 060° at 8 knots; visibility 8 miles; skies broken at 900 feet and overcast at 1,400 feet; temperature minus 3° C; dew point temperature minus 5° C…Remarks [cloud] ceiling varying between 700 to 1,100 feet.
>
> The 0944 METAR indicated the following:
>
> wind 070° at 7 knots; visibility 6 miles; skies overcast at 600 feet; temperature minus 3° C; dew point temperature minus 4° C…Remarks [cloud] ceiling varying between 400 and 900 feet.

The PUB ASOS provides unofficial weather observations that are recorded every 5 minutes. At 0910, the PUB ASOS indicated the following: winds 070° at 7 knots and 6 sm in mist. At 0915, the PUB ASOS indicated the following: winds 060° and visibility 8 sm. Both reports reported the following: clouds broken at 900 feet and overcast at 1,400 feet, temperature -3° C, and dew point -4° C.

1.7.3 Additional Icing Information

Scientists from the National Center for Atmospheric Research (NCAR), Boulder, Colorado, conducted studies for the National Transportation Safety Board to determine whether the accident airplane encountered supercooled[26] large droplet (SLD) conditions, which are more conducive to the accumulation of thin, rough ice on or aft of the protected surfaces, and to estimate the amount of airframe ice accumulation. NCAR reported that, on the basis of surface, radar, upper air, and satellite data, the airplane likely encountered SLD conditions from about 9,400 to 6,100 feet (the calculated altitude at which the upset occurred). NCAR indicated that, during the time that the airplane was in this cloud layer (about 4 1/2 minutes), from 1 to 4 millimeters (mm) (0.039 to 0.157 inch) of ice likely accumulated along the wing leading edges.[27] Severe icing conditions are those in which 5 mm (0.195 inch) of ice accumulates in 5 minutes.

Several pilot reports (PIREP) were provided around the time of the accident in the area over PUB. A PIREP received about 0646 from a pilot flying a Swearingen Merlin IV reported moderate mixed icing on final approach to runway 8. A PIREP received about 0809 from the pilot flying a Hawker jet who had landed on runway 8 about 1 minute earlier reported light to moderate and/or mixed icing and a "little" ice accumulation on the wing leading edges. A PIREP received about 1020 from a pilot flying a Learjet 31 reported light to moderate rime icing on final approach to runway 8. An urgent PIREP[28] received about 1023 from a pilot flying a Beechcraft King Air 90 at an altitude of about 6,000 feet reported moderate mixed icing and ice accumulation from 1/4 to 1/2 inch on final approach to runway 8.

1.8 Aids to Navigation

No problems with any navigational aids were reported.

1.9 Communications

No communications problems between the pilots and any of the air traffic controllers who handled the accident flight were reported.

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[26] Supercooled is the liquid state of a substance that is below the normal freezing temperature for that substance.

[27] The ice accumulation estimates do not account for all of the effects of SLD conditions, including the effect of the droplets' running aft of the protected surfaces before freezing.

[28] FAA Order 7210.3, "Facility Operation and Administration," states that weather phenomena reported by a pilot that represents a hazard or a potential hazard to flight operations, including severe icing, should be disseminated as "urgent PIREPs."

1.10 Airport Information

PUB is located about 5 nm southeast of Pueblo at an elevation of 4,726 feet. PUB has one set of parallel runways, 8L/26R and 8R/26L, and runway 17/35.

1.10.1 Air Traffic Control

PUB has a combined tower and radar approach control facility. The tower is located on the south side of the airport, left of and about midway down runway 26R. PUB tower controllers use DBRITE (digital bright radar indicator tower equipment), which provides a visual display of the airport surveillance radar (ASR)-7 data and radar and beacon signals received from the PUB automated radar terminal system IIE radar processing system.

1.10.2 Air Traffic Control Guidance

FAA Order 7110.65, "Air Traffic Control," paragraph 2-6-3, "PIREP Information," states that, when an air traffic controller receives a PIREP that involves icing, the controller should record the icing type and intensity and the air temperature in which the icing is occurring. The order states that controllers are required to "relay pertinent PIREP information to concerned aircraft in a timely manner" and the flight service station (FSS) "serving the area in which the report was obtained."

As noted previously, about 0809 (about 1 hour before the accident), the pilot of a Hawker jet, who had flown inbound to PUB from the southeast and had just landed, reported to the PUB local controller that a little bit of ice had accumulated on the airplane's wing leading edges. The controller asked the pilot if the icing conditions were "moderate mixed," and the pilot replied that the icing conditions were "light to moderate but it looks like it's mixed." The controller did not provide the PIREP to the accident flight crew or to the Denver FSS. In postaccident interviews, the controller stated that he had interpreted the pilot's statement as "a trace or less" of ice and, therefore, not a reportable amount.

FAA Order 7110.65, Section 9, "Automatic Terminal Information Service Procedures," paragraph 2-9-1, "Application," states that controllers should "use the ATIS information, where available, to provide advance non-control airport/terminal area and meteorological information to aircraft." ATIS information includes the landing runway in use; however, air traffic controllers are allowed to amend the ATIS information at any time as situations change. ATIS information "Juliet," which was effective at 0753, broadcast that the landing runway in use at PUB was 8L; however, at 0905:56, the PUB local controller instructed the flight crew to expect to land on runway 26R. During postaccident interviews, the controller stated that he was often asked by corporate pilots to use the runway opposite that being advertised on ATIS and that, as a service, he would provide the closest runway as a matter of course as long as the winds allowed it.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The accident airplane was equipped with a B&D Instruments and Avionics CVR, serial number A01148. The exterior of the CVR exhibited slight structural damage. The CVR was sent to the Safety Board's laboratory in Washington, D.C., for readout and evaluation. The tape was played back normally and without difficulty. The recording consisted of three separate channels of good quality audio information:[29] the captain and first officer audio panels and the cockpit area microphone (CAM). A transcript was prepared of the entire 31-minute, 36-second recording (see appendix B).

1.11.1.1 Cockpit Voice Recorder Sound Spectrum Study

The accident CVR recording was examined using computer signal and spectrum analyzers[30] at the Safety Board's laboratory to determine whether the stall warning system generated any aural alerts during the last 60 seconds of the flight. Specifically, the CAM channel was examined to determine whether any sounds could be identified that corresponded to the rotation rate of the stickshaker motor or weights. The study showed that the stall warning appears to have activated at 0912:44.5 (about 1 second after the loss of control) and continued to 0912:50.5. The stall warning appears to have reactivated at 0912:53.4 and continued to 0912:54.5 (the end of the recording).

1.11.2 Flight Data Recorder

The airplane was not equipped with a flight data recorder nor was it required to be so equipped.[31]

1.12 Wreckage and Impact Information

The airplane wreckage was located about 4 nm east of runway 26R at an elevation of about 4,600 feet. The debris field was about 550 feet long and extended along a 230° magnetic heading. All of the airplane's major structures, including the cockpit, wings,

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[29] The Safety Board rates the quality of CVR recordings according to a five-category scale: excellent, good, fair, poor, and unusable. See appendix B for a description of these ratings.

[30] The computer signal analyzer provides detailed analysis of the analog waveform and provides the specific frequency content of the signals and detailed timing information. The spectrum analyzer provides a visual presentation of the frequency content of the recorded signals.

[31] On December 22, 2003, the Safety Board issued Safety Recommendation A-03-65, which recommended that the FAA require that all turbine-powered aircraft manufactured before January 1, 2007, being used for commercial or corporate purposes under Part 91 be retrofitted with a crash-protected image recording system by January 1, 2010. The Board reiterated Safety Recommendation A-03-65 on January 24, 2006. For additional information, see National Transportation Safety Board, *Collision with Trees and Crash Short of Runway, Corporate Airlines Flight 5966, British Aerospace BAE-J3201, N875JX, Kirksville, Missouri, October 19, 2004,* Aircraft Accident Report NTSB/AAR-06/01 (Washington, DC: NTSB, 2006).

fuselage, and empennage were found at the accident site. The main wreckage consisted of a section of the airframe from the aft pressure bulkhead to the cockpit. The cockpit was consumed by fire, and the instrument panel was crushed. The throttle quadrant was melted, and only stubs of the control handles were present. The left and right wings were found separated from the fuselage. The position of the landing gear actuators was consistent with the landing gear being in the down-and-locked position at impact.

Evidence of a postcrash fire was found along the debris field, beginning about 55 feet after the initial impact marks. Both engines were found separated from the airplane. The engines showed no indications of uncontainment, case rupture, or in-flight fire. Both engines were disassembled at PWC's facility in Bridgeport, West Virginia, under Safety Board supervision. Disassembly of the engines revealed no preexisting defects or malfunctions.

1.13 Medical and Pathological Information

Fluid and tissue specimens obtained from the captain and a fluid specimen obtained from the first officer were transported to the FAA's Civil Aerospace Medical Institute for toxicological analysis. The specimens tested negative for alcohol and a wide range of drugs, including drugs of abuse.[32]

1.14 Fire

No evidence of an in-flight fire was found.

1.15 Survival Aspects

According to the Pueblo County Coroner's Office autopsy report, the cause of death for the captain, first officer, and six passengers was "multiple traumatic injuries."

1.16 Tests and Research

1.16.1 Enhanced Ground Proximity Warning System Data Study

The EGPWS computer, which contained two flash memory chips, was recovered on site. One of the memory chips exhibited several visible cracks to the package, and the other chip was found undamaged. The two memory chips were sent to Honeywell's facility in Redmond, Washington, for examination and data recovery.

[32] The drugs tested in the postaccident analysis include (but are not limited to) marijuana, cocaine, opiates, phencyclidine, amphetamines, benzodiazapines, barbiturates, antidepressants, antihistamines, meprobamate, and methaqualone.

Honeywell could only recover EGPWS data from the undamaged memory chip. EGPWS data from 12 flight parameters, including altitude, ground speed, descent rate, pitch, roll, and ground track, were available on the undamaged chip for about the last 30 seconds of the flight. A flight simulation conducted using the EGPWS data indicated that two EGPWS alerts had been recorded; however, the identification of the alert types was contained on the damaged chip and, therefore, the alert types could not be identified. Further, the EGPWS data were compared with the radar-data-based calculations and showed a good correlation with the calculations up to about 2 to 3 seconds into the loss of control, after which time the data were considered unreliable because of the large dynamic movements of the airplane.

1.16.2 Airplane Performance Study

The Safety Board conducted an airplane performance study using EGPWS data, PUB ASR-7 radar data, manufacturer-provided aerodynamic data, and meteorological information to establish a time history of the airplane's motions and to estimate the airplane's performance parameters (including ground speed, airspeed, descent rate, and aircraft pitch and roll angles) for the final portion of the flight. Nominal error or uncertainty in the radar and wind data led to variables in the airplane performance parameters; therefore, the performance parameters should be considered approximations.

According to the airplane performance study, the airplane started its final descent from 7,000 feet at an airspeed of about 155 knots about 0911:26. Over about the next 30 seconds, the descent rate was about 800 feet per minute (fpm). By about 0912:30, as the airplane was passing through about 6,200 feet, the descent rate had decreased to about 490 fpm, and the airspeed had decreased to about 98 knots. Over the next 10 seconds, the airspeed continued to decrease to about 90 knots. Immediately after passing through about 6,100 feet, the airplane experienced the onset of a large roll to the left concurrent with a sudden decrease in the pitch angle, consistent with the motion of an airplane that has experienced an aerodynamic stall.

1.17 Organizational and Management Information

At the time of the accident, Circuit City Stores, Inc., which is headquartered in Richmond, Virginia, owned and maintained operational control of the accident airplane, another Cessna 560 airplane (the sister ship), and a Cessna Citation 650 airplane. Martinair, Inc., is a Part 135 aircraft charter and management company that began operations in July 1986. Martinair has provided pilots and maintenance support for Circuit City Stores airplanes through a management services agreement since 1993. At the time of the accident, Martinair managed 15 aircraft, operated 11 aircraft, and had 33 full- and part-time pilots and 8 aircraft mechanics. Martinair's chief pilot stated that, although Circuit City Stores flights fell under 14 CFR Part 91 operating rules, company pilots generally adhered to Part 135 operating rules for these flights and used the same checklists and standard operating procedures used for Part 135 flights.

1.17.1 Operational Guidance

1.17.1.1 Normal Operations

According to the SimuFlite Cessna Citation V Technical Manual,[33] a typical ILS approach should be flown, in part, as follows:

> When established on the localizer inbound to the FAF [final approach fix], ensure that flaps are set to T.O. [takeoff] and APPR [approach].
>
> Maintain airspeed at V_{ref}+20+wind factor and initiate the Before Landing checklist…
>
> At glideslope intercept, start timing, begin descent, and extend full flaps. Complete Before Landing checklist to the autopilot/yaw damper.
>
> Maintain airspeed at V_{ref}+10+wind factor…
>
> Reduce power slightly to ensure crossing the runway threshold at V_{ref}+wind factor.

Martinair's Operations Manual stated that, under normal circumstances, the airspeed on final must be held at V_{ref}+10 ±5 knots and that the airspeed must be bled off to V_{ref} at the runway threshold.

1.17.1.2 Operations in Icing Conditions

The SimuFlite Cessna Citation V Technical Manual contains the following warning: "with any residual ice present do not attempt to fly uncorrected V_{ref}/V_{app}[34] speeds. Stall speeds increase and stall warning margins decrease." The technical manual also contains the following caution:

> In icing conditions, a small amount of residual ice forms on unprotected areas. This is normal, but can cause an increase in stall speeds. When any amount of residual ice is visible, the stall speeds increase by 8 knots; the V_{ref}/V_{app} speeds and landing distances and the maximum landing weight permitted by brake energy must be corrected.

Assuming some residual icing was present on the airplane's surfaces during the accident flight, the corrected V_{ref} would have been 104 knots. At 0859:29, the CVR recorded the first officer stating that the V_{ref} was 96 knots.

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[33] The guidance for operating in icing conditions in the Simuflite Cessna Model 560 Citation V Technical Manual, which was used as the training manual for Martinair pilots, is in accordance with the guidance contained in the Cessna Model 560 Citation V AFM.

[34] V_{app} is the landing approach airspeed with approach flaps and landing gear up.

1.17.1.3 Anti-Ice and Deice Systems Usage

According to the SimuFlite Cessna Citation V Technical Manual, when operating in visible moisture and when the outside air temperature is between -30° and +10° C, the pitot static heat and engine anti-ice systems should be turned to ON. The manual also states that, if the temperature is above -18° C, the windshield bleed air switch should be turned to LOW, and, if the temperature is below -18° C, the windshield bleed air switch should be turned to HIGH.

According to SimuFlite's technical manual (and the Cessna AFM), the surface deice boots should be used when ice buildup is estimated to be between 1/4- to 1/2-inch thick. The manual further states, "Early activation of the boots may result in ice bridging[35] on the wing, rendering the boots ineffective. Late activation (if accumulation is more than 1/2-inch thick) may not clear the ice." The manual also states the following:

> When reconfiguring for approach and landing…with any ice accretion visible on the wing leading edge, regardless of thickness, activate the surface deice system. Continue to monitor the wing leading edge for any reaccumulation.

1.17.2 Flight Crew Training

Martinair provides initial in-house ground school training to company pilots. After the in-house training, pilots attend flight simulator training at CAE SimuFlite.

1.17.2.1 Operations in Icing Conditions

During postaccident interviews, several SimuFlite instructors stated that guidance on operations in icing conditions is taught in initial and recurrent ground school. The training includes a review of the anti-ice and deice systems and their usage and anti-ice failure scenarios. The instructors also stated that icing operations in the simulator involved introducing ice on the wings. Pilots are taught to activate the deice boots after about 1/4 to 1/2 inch of ice has accumulated on the wings and to use the anti-ice systems when flying in visible moisture[36] and when the outside air temperature is between -30° and +10° C.

According to the SimuFlite instructors, the specific items to be covered during simulator training on operations in icing conditions are left to the discretion of the individual instructors. A review of SimuFlite's training syllabus also revealed that no specific instruction exists to evaluate a pilot's performance of the AFM procedures to increase the airspeed and operate the deice boots during approaches when ice is present on the wings. Further, one of the SimuFlite Cessna 560 instructors was unaware of these AFM procedures. Investigators also interviewed a Cessna 560 instructor from another

[35] Ice bridging is a phenomenon in which ice in the shape of an inflated deice boot forms after the boot is cycled. Ice bridging had been known to occur on older deice boot designs that used larger tubes and lower pressures, resulting in slower inflation and deflation rates.

[36] The manual indicates that visible moisture includes, but is not limited to, the following conditions: fog with visibility less than 1 mile, wet snow, and rain.

major flight training center, and he stated that, although he believed that each instructor emphasized the icing approach procedures during simulator training, the center's syllabus contained no instruction to ensure that the instructors are evaluating the procedures.

1.17.2.2 Stall Recovery

A SimuFlite instructor indicated that stalls in the clean, takeoff, and landing configurations are covered during training and checkrides. He stated that stall recovery in the Cessna 560 should be initiated at stickshaker activation and that recovery from an impending stall consisted of adding maximum power while conserving the altitude as much as possible.

1.18 Additional Information

1.18.1 Cessna 550 and 560 Airplanes Icing-Related Flight Testing and Subsequent Actions

In early 1996, the FAA conducted preliminary evaluations of the Cessna 560 stall speeds and characteristics when operating in icing conditions. The evaluations were conducted partially as the result of the following icing-related Cessna 550[37] and 560 accidents:[38]

- On December 30, 1995, a Cessna 560 crashed while circling to land in icing conditions in Eagle River, Wisconsin.[39] The investigation revealed that about 1/8 inch of rime ice had accumulated on the left wing and horizontal stabilizer leading edges.
- On January 2, 1996, a Cessna 560 crashed while on final approach in icing conditions in Augsburg, Germany.[40] The pilots reported that the airplane started to buffet, entered a stall, and rolled right. No stall warnings were activated during the flight. The investigation by the German Federal Bureau of Accidents Investigation (BFU) revealed that about 2 mm (0.078 inch) of ice had accumulated along the wing leading edges.

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[37] The airfoil used on model 560 series airplanes is a modified version of the airfoil used on model 550 series airplanes. The main spar height is the same; however, the leading edge and the upper surface curvature have been changed to improve high airspeed performance.

[38] The FAA also noted that several test pilots from its training academy had reported concerns about the Cessna 560's stall handling characteristics.

[39] The description of this accident, CHI96FA067, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[40] For more information, see German Federal Bureau of Accidents Investigation, *Report on the Accident to the Aircraft Cessna 560 on January 2, 1996, at Augsburg,* File No. CX 001-0/96 (Braunschweig City, Germany: BFU, 1996).

- On February 19, 1996, a Cessna 550 crashed while on final approach in Salzburg, Austria.[41] On the basis of radar recordings and witness testimony, the BFU determined that the airplane entered a stall, banked left, and became uncontrollable. The BFU stated that heavy icing at low altitudes prevailed during the approach and that the accident "happened because the minimum control airspeed was undershot during the final approach."

As a result of flight tests conducted in early 1996 with the Cessna 560, the FAA issued Priority Letter Airworthiness Directive (AD) 96-24-06, which was applicable to the Cessna 560, in November 1996. AD 96-24-06 required revising the Cessna Model 560 Citation V AFM to provide flight crews with airspeed limitations, deice system operational procedures, and landing performance information to be used during approach and landing when residual ice was present or expected to prevent the uncommanded roll of the airplane in such conditions.

In late 1996, with Cessna participation, the FAA conducted additional flight tests with Cessna 550 and 560 series airplanes to assess the airplanes' stall speeds, warnings, and characteristics. The FAA conducted the flight tests using airplanes with and without 1/2-inch-thick ice shapes installed on the protected (that is, those surfaces with deice boots) and unprotected surfaces of the wing.[42] The flight tests of the Cessna 550 revealed that the airplane had an acceptable stall warning margin with and without the ice shapes installed. The flight tests of the Cessna 560 revealed that the stall warning margin was insufficient with and without ice shapes installed.[43]

Specifically, the flight tests of the Cessna 560 revealed that, even without ice shapes installed, the stall warning system activated only about 1 to 2 knots before a significant lateral roll tendency and subsequent stall occurred. The tests also showed that, with ice shapes installed, the stall warning system activated shortly after or concurrent with a stall and a subsequent significant lateral roll. The tests indicated that the stall speed increased from 3 to 5 knots with the ice shapes installed and that the stall warning system did not compensate for the increased stall speed.

In early 1999, Cessna began incorporating modified stall warning systems on the Cessna 560 airplane (including the accident airplane) to provide a sufficient stall warning margin for operations in icing conditions. The modifications resulted in a stall warning margin increase of about 5 knots and were outlined in Cessna Service Bulletins (SB) SB560-34-69 and SB560-34-70. On April 3, 2000, the FAA issued AD 2000-03-09,

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[41] An English translation of the full accident report was not available; however, an English summary of the findings and the probable cause was provided to investigators by the BFU.

[42] At the time of the Cessna 560 certification flight tests, artificial ice shapes were not required to be installed on the protected surfaces of the airplane. According to the original Cessna 560 flight testing certification, the flight tests were conducted in natural icing conditions and with artificial ice shapes installed on the unprotected surfaces of the airplane. According to the FAA, 1/2-inch ice shapes were used for the 1996 tests because these shapes represented the type of ice accumulated during the most likely encountered icing conditions and because the Cessna Model 560 Citation V AFM instructed pilots to activate the deice boots when ice accumulation was estimated to be from 1/4- to 1/2-inch thick.

[43] Title 14 CFR 25.207 requires that the stall warning begin at a speed exceeding the stall speed by a margin of not less than 5 knots.

which superseded AD 96-24-06. AD 2000-03-69 retained the requirements contained in AD 96-24-06 and added a requirement to mandate the modifications outlined in Cessna SBs SB560-34-69 and SB560-34-70. The FAA indicated that the modified stall warning systems would also protect against the undesirable stall characteristics exhibited during the previous icing-related Cessna accidents and the 1996 ice shape tests.

1.18.2 Previous Icing-Related Safety Recommendations

The Safety Board has previously issued numerous icing-related safety recommendations, several of which are on the Safety Board's List of Most Wanted Transportation Safety Improvements. Five previously issued icing-related safety recommendations are relevant to the Pueblo accident and are detailed in this section. One of these recommendations was issued as a result of the investigation of the October 31, 1994, accident involving American Eagle flight 4184, which crashed during a rapid descent after an uncommanded roll excursion during icing conditions.[44] The other four relevant recommendations were issued as a result of the investigation of the January 9, 1997, accident involving Comair Airlines, Inc., flight 3272, which experienced a loss of control while maneuvering with ice accumulation on the wings.[45]

1.18.2.1 Deice Boot System Activation

During the Comair flight 3272 accident investigation, the Safety Board learned that the AFMs for many aircraft, including the Cessna 560, instructed pilots to delay initial deice boot activation until they observed 1/4- to 1/2-inch-thick ice accumulation on the wing surface. Further, the Cessna Model 560 Citation V AFM states, "early activation of the boots may result in ice bridging on the wing." Additionally, Advisory Circular (AC) 25.1419-1A, "Certification of Transport Category Airplanes for Flight in Icing Conditions," dated May 7, 2004, states, "many AFMs specify ice accumulation thickness prior to activation of the deicer boot system. The practice originates from a belief that a bridge of ice could form if boots are operated prematurely." However, the AC further states the following:

> Although ice may not shed completely by one cycle of the boots, this residual ice will usually be removed during subsequent boot cycles and does not act as a foundation for a bridge to form. The AFM procedure for boot operations should be to operate the boots at the first sign of ice and not wait for a specific amount of ice to accumulate.

[44] For additional information, see National Transportation Safety Board, *In-flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a. American Eagle Flight 4184, Avions de Transport Regional (ATR) Model 72-212, N401AM, Roselawn, Indiana, October 31, 1994; Volume I Safety Board Report,* Aircraft Accident Report NTSB/AAR-96/02 (Washington, DC: NTSB, 1996).

[45] For additional information, see National Transportation Safety Board, *In-Flight Icing Encounter and Uncontrolled Collision With Terrain, Comair Airlines, Inc., Flight 3272, Embraer EMB-120RT, N265CA, Monroe, Michigan, January 9, 1997,* Aircraft Accident Report NTSB/AAR-98/04 (Washington, DC: NTSB, 1998).

Additionally, information gathered at a 1997 Airplane Deice Boot Bridging Workshop, which included participants from the FAA and the National Aeronautics and Space Administration (NASA); subsequent icing tunnel studies; and flight tests conducted as part of the Comair investigation revealed no evidence that modern turbine-powered airplanes (that is, airplanes equipped with high-pressure, segmented pneumatic deice boots that quickly inflate and deflate) were at risk for ice bridging. Further, a search of the Safety Board's accident database revealed no accidents related to ice bridging.

The icing tunnel tests, wind tunnel data, and existing icing research data revealed that thin (1/4 inch or less), rough ice accumulations on the wing leading edge deice boot surfaces could be, depending on distribution, as aerodynamically detrimental to an airplane's performance as larger ice accumulations and that such ice could be difficult for pilots to perceive. As a result of these findings, the Safety Board issued Safety Recommendation A-98-91, which asked the FAA to do the following:

> Require manufacturers and operators of modern turbopropeller-driven airplanes in which ice bridging is not a concern to review and revise the guidance contained in their manuals and training programs to emphasize that leading edge deicing boots should be activated as soon as the airplane enters icing conditions.

On July 16, 1999, the FAA issued Notice for Proposed Rulemaking (NPRM) 99-NM-136-AD, which was applicable to Cessna model 500, 501, 550, 551, and 560 series airplanes and proposed revising the applicable AFMs to include a requirement to activate the deice boots at the first sign of ice accumulation and to cycle the boots automatically, if the automatic mode was available, or to cycle the boots manually to minimize ice accumulation on the airframe. From July 1999 to March 2000, the FAA issued 18 similar NPRMs applicable to 14 CFR Part 23 airplanes and 21 NPRMs applicable to Part 23 and 25 airplanes equipped with pneumatic deice boots.[46]

In an August 12, 1999, letter to the FAA, Cessna requested that NPRM 99-NM-136-AD be withdrawn, contending that the affected airplanes' service history in icing conditions, the modifications made to the airplanes' stall warning systems, and the minimum airspeed in icing conditions guidance contained in its AFM validated that the airplanes could operate safely in icing conditions and that, therefore, the NPRM was not warranted. In a September 25, 2000, response letter to Safety Recommendation A-98-91, the FAA stated that it withdrew NPRM 99-NM-136-AD in November 1999 because manufacturer's data indicated that the affected aircraft could operate safely with ice accretion on the protected surfaces. The FAA also withdrew six of the other NPRMs it issued from July 1999 to March 2000 for similar reasons.

On May 19, 2003, the FAA informed the Safety Board about recommendations an Aviation Rulemaking Advisory Committee (ARAC) Ice Protection Harmonization Working Group (IPHWG) had made to revise Parts 25 and 121. The proposed revisions

[46] In a March 12, 2000, response letter, the Safety Board expressed concern that the proposed ADs would require that the deice boot system be activated at the first sign of ice accumulation, not as soon as the airplane enters icing conditions.

would add a requirement that operators' guidance state that the deice system be activated as soon as the airplane enters icing conditions.[47] However, in the intervening 3 years, the FAA has taken no further action; therefore, on May 10, 2006, the Board classified Safety Recommendation A-98-91 "Open—Unacceptable Response," pending issuance of a final rule adopting the regulatory changes proposed by the ARAC IPHWG.

1.18.2.2 Certification Requirements for Flight into Icing Conditions

The Safety Board determined during the American Eagle flight 4184 accident investigation that SLD conditions can cause ice accretions that are more aerodynamically detrimental than those that were considered during the initial certification of many existing airplanes for flight in icing conditions (that is, those conditions that fell within the Part 25, Appendix C envelope).[48] As a result, the Board issued Safety Recommendation A-96-54 (superseding Safety Recommendation A-81-116), which asked the FAA to do the following:

> Revise the icing criteria published in 14…CFR Parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the Appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.

Safety Recommendation A-96-54 was reiterated in the Comair flight 3272 accident report and is currently on the Safety Board's List of Most Wanted Transportation Safety Improvements. In a March 6, 2006, letter, the FAA stated that the ARAC IPHWG is continuing to develop a revision to Part 25 to require a demonstration that an airplane can safely operate in SLD conditions for an unrestricted time or can detect SLD and safely exit icing conditions.

The Safety Board noted in its May 10, 2006, letter that, although the work of the IPHWG is responsive to this recommendation, the actions are proceeding at an unacceptably slow pace and that the FAA has not yet received the recommendations from the IPHWG, prepared regulatory analyses, issued an NPRM, analyzed comments, or completed the many other tasks involved in issuing new regulations. Pending development and issuance of regulatory requirements for both Part 23 and 25 airplanes to demonstrate that they can safely operate in SLD conditions for an unrestricted time or can detect the SLD and safely exit icing conditions, the Board classified Safety Recommendation A-96-54 "Open—Unacceptable Response."

The Safety Board also determined during the Comair flight 3272 accident investigation that the ice accretions and conditions considered during certification for

[47] The ARAC IPHWG also stated that an operator's guidance could only state that the deice system should be activated at the first sign of ice accumulation if the operator had demonstrated through additional flight tests that the airplane could operate safely with some ice accumulation.

[48] Part 25, Appendix C specifies the kind of icing conditions in which an airplane's ice protection system must be able to operate.

flight into icing conditions were not representative of all types of ice that could be encountered while operating in icing conditions, including rough ice accretions of less than 1/4 inch, which can severely degrade an airplane's performance. Further, the effects of delayed anti-ice and deice system activation, intercycle ice accretions,[49] or residual ice accretions were not addressed in the icing certification rules. Therefore, the Board issued Safety Recommendations A-98-92 and -100, both of which are currently on the Board's List of Most Wanted Transportation Safety Improvements. Safety Recommendation A-98-92 asked the FAA to do the following:

> Conduct additional research to identify realistic ice accumulations, to include intercycle and residual ice accumulations and ice accumulations on unprotected surfaces aft of the deicing boots, and to determine the effects and criticality of such ice accumulations; further, the information developed through such research should be incorporated into aircraft certification requirements and pilot training programs at all levels.

In a September 21, 2001, response letter, the FAA indicated that sufficient information and methods were not available at that time to provide additional guidance concerning the determination of critical ice shapes in aircraft certification and that, therefore, it would sponsor additional needed research. In an October 26, 2005, response letter, the FAA indicated that it had completed and would shortly issue a draft revision to AC 20-73, "Aircraft Ice Protection," which included the certification guidance on determining critical ice shapes, descriptions of intercycle and residual ice accretions, and the aerodynamic penalties associated with these ice shapes. Although the FAA issued AC 20-73A on August 16, 2006, Safety Recommendation A-98-92 remains classified "Open—Unacceptable Response," pending the receipt of information regarding any new research conducted in response to this recommendation.

The Safety Board also issued a safety recommendation concerning the determination of critical ice shapes, A-98-100, to the FAA, which stated the following:

> When the revised icing certification standards [recommended in Safety Recommendation A-98-92] and criteria are complete, review the icing certification of all turbopropeller-driven airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards.

On November 4, 2005, in response to Safety Recommendation A-98-100, the FAA issued an NPRM titled, "Airplane Handling Characteristics in Icing Conditions," which proposed to revise 14 CFR 25.143, "Proof of Compliance," by adding a new paragraph, (i)(1), that specifies the certification requirements for airplane performance or handling qualities for flight in icing conditions and the type of ice accretions (including the size, shape, and location) that must be used to demonstrate compliance in each phase of flight. Specifically, the NPRM stated that thin, rough ice accretions must be considered to show

[49] Intercycle ice is ice that has accreted on the deice surface between boot activation cycles.

compliance with proposed paragraph 25.143(i)(1). In its January 2006 comments on the NPRM, the Safety Board stated that it agreed with the intent of the NPRM and added that the ice used to demonstrate compliance with proposed paragraph 25.143(i)(1) should accurately represent thin, rough ice accretions, which can cause severe aerodynamic penalties.

On November 4, 2005, the FAA also proposed AC 25-1X, "Performance and Handling Characteristics in the Icing Conditions Specified in Part 25, Appendix C," which was intended to provide guidance for implementing the regulations proposed in the NPRM. In its January 2006 comments on the proposed AC, the Safety Board noted that the results of the research conducted as a part of the Comair flight 3272 accident investigation are currently included in Appendix R of draft AC 20-73, "Aircraft Ice Protection." Appendix R, which is also referenced in Appendixes 1 and 2 of proposed AC 25.21-1X, includes guidance on determining critical ice shapes and their associated roughness, descriptions of intercycle and residual ice accretions, and the aerodynamic penalties associated with these ice shapes.[50]

Although the Safety Board agreed with the FAA's proposed regulatory changes, in its May 10, 2006, response letter, the Board noted that the FAA has not applied the new information to all in-service turbopropeller-driven airplanes. Although the FAA indicated that no airplanes have an unsafe condition, the Board stated that it was concerned that the FAA reached this conclusion based on its belief that no accidents or serious incidents had occurred related to this issue. However, the Board stated that, during the 1990s, a number of accidents had occurred involving airplanes that had passed the certification standards and for which the FAA believed there was no unsafe condition requiring action and that these accidents generated new information that the FAA could now use. The Board stated that, to meet the intent of Safety Recommendation A-98-100, the FAA would need to formally evaluate (perhaps by conducting flight tests) all in-service turbopropeller-driven aircraft to ensure that these aircraft comply with all current icing certification criteria for new aircraft. The Board asked the FAA to provide a list of the aircraft that it had formally evaluated and a summary of the findings and resultant actions. Pending receipt of this information, Safety Recommendation A-98-100 was classified "Open—Unacceptable Response."[51]

1.18.2.3 Stall Warning Margins

The Safety Board also determined during the Comair flight 3272 investigation that the stall warning did not activate until after the stall, as in this accident, because ice accumulation on the airplane had increased the stall speed and that the stall warning system was not designed to account for the increase caused by the type of ice that had

[50] For more information about the testing conducted to determine the effects of residual and intercycle ice accretions, see section 1.18.3.

[51] Safety Recommendation A-98-100 is on the Safety Board's List of Most Wanted Transportation Safety Improvements. Accordingly, Safety Recommendation A-07-16, which supersedes Safety Recommendation A-98-100, will automatically be placed on the Most Wanted List.

accreted on the airplane. As a result, the Board issued Safety Recommendation A-98-96, which asked the FAA to do the following:

> Require manufacturers and operators of all airplanes that are certificated to operate in icing conditions to install stall warning/protection systems that provide a cockpit warning (aural warning and/or stick shaker) before the onset of stall when the airplane is operating in icing conditions.

In a September 21, 2001, response letter, the FAA stated that it was pursuing regulatory development projects that would require both new and in-service airplanes to have stall warning systems installed that provide a cockpit warning before the onset of a stall when operating in icing conditions. However, in an October 26, 2005, response letter, the FAA stated that, after further review, it had determined that such a requirement for all in-service airplanes would impose a cost burden not commensurate with the potential safety benefits and that, therefore, it would take appropriate action on in-service airplane designs only if an unsafe condition were identified.

The November 2005 NPRM proposed changes to 14 CFR 25.207 to require that newly type-certificated airplanes be equipped with stall warning systems that provide a stall warning before the onset of a stall when the airplane is operating in icing conditions. In its comments on the NPRM, the Safety Board stated that the proposed changes appear to address the intent of Safety Recommendation A-98-96 for newly type-certificated airplanes; however, the proposed changes do not address in-service airplanes. Further, in its May 2006 response letter, the Board stated that it was not acceptable for the FAA to wait until an accident or serious incident occurred to reveal that an unsafe condition existed on an in-service airplane. As a result, the Board classified Safety Recommendation A-98-96 "Open—Unacceptable Response," pending issuance of a final rule associated with the November 2005 NPRM that includes a requirement that both newly type-certificated and in-service airplanes be equipped with stall warning systems that provide a cockpit warning before the onset of a stall in icing conditions.

1.18.3 Residual and Intercycle Ice and Automatic Deice Boot System Information

In May 2002, as a result of additional testing conducted during the Comair flight 3272 investigation, the FAA published a report titled, *Effect of Residual and Intercycle Ice Accretions on Airfoil Performance*,[52] which presented the results of testing designed to characterize and evaluate the aerodynamic performance effects of residual and intercycle ice accretions resulting from the cyclic operation of a typical aircraft deice boot system.[53] The tests were conducted using a scaled version of the EMB-120 airfoil outboard wing section, which is similar to the Cessna Citation airfoil, and liquid water

[52] Federal Aviation Administration, Office of Aviation Research, *Effect of Residual and Intercycle Ice Accretions on Airfoil Performance,* DOT/FAA/AR-02/68 (Washington, DC: 2002).

[53] Some pneumatic deice boot systems can be turned on and activated automatically at either slow/low (3-minute) or fast/high (1-minute) cycle intervals. Cessna Citation series airplanes are not equipped with automatic deice boot recycling systems.

contents and mean volumetric diameters that fell within the current envelopes for known icing certification. During the tests, the deice boots were cycled at both 1- and 3-minute intervals.

Results from the icing tests showed that the intercycle ice accretions were much larger in size and surface extent than residual ice accretions and that the intercycle ice shapes caused significant performance degradation. The testing showed that the deice boots generally removed the ice from the wing leading edge and left little residual ice. A single continuous maximum case was run with 1-minute boot cycles, which was found to be very effective in minimizing the size of the intercycle ice accretion. The tests also revealed that the deice boot system was equally effective at shedding ice when activated at the first sign of ice as when activated once a 1/4 inch of ice had accumulated. The FAA's test report recommended the "early and often" approach to deicing (that is, activating the deice boots as soon as ice is detected and cycling the boots at 1-minute intervals) to limit the size of residual and intercycle ice accretions.

On May 7, 2004, the FAA issued AC 25.1419-1A, which stated the following.

> The recommended AFM procedure for boot operation should be to operate the boots at the first sign of ice. … The boots should be operated until icing conditions are exited and ice no longer adheres to the airframe.

On July 21, 2004, the FAA issued revised AC 23.1419-2C, "Certification of Part 23 Airplanes for Flight in Icing Conditions," which reiterated the FAA's technical report findings and added the following:

> For deicing systems that do not have a timer to cycle the system automatically once activated, the additional task of manually cycling deicing systems on pilot workload should be evaluated. A recent Part 23 applicant found that definition of airframe deicing boot intercycle and residual ice steered them toward one-minute boot cycles and the workload evaluation dictated an automatic timer for the boots.

2. Analysis

2.1 General

The captain and first officer were properly certificated and qualified under Federal regulations. No evidence indicated any preexisting medical or physical condition that might have adversely affected the flight crew's performance during the accident flight. A review of the pilots' 72-hour histories revealed that the pilots slept well in the days leading up to the accident flight and went to bed early in preparation for an early departure. No evidence was found that fatigue degraded the performance of either pilot on the day of the accident.

The weight and balance of the airplane were within landing limits.

The recovered components showed no evidence of any preexisting powerplant, structural, or system failures.

The PUB local controller did not provide the accident flight crew or the Denver FSS with the PIREP reporting light to moderate icing; however, this was not a factor in the accident because CVR information indicated that the flight crew was aware of the icing conditions.

During the approach, the flight crew of the sister ship, which was following the accident flight, cycled the deice boots numerous times and maintained a high airspeed and, subsequently, landed safely, indicating the importance of taking these actions to counteract the hazardous effects of icing.

This analysis discusses the accident sequence, including the flight crew's performance. This analysis also discusses inadequate training on operations in icing conditions, inadequate deice boot system operational guidance, the need for automatic deice boot systems, inadequate icing flight test certification requirements, and inadequate stall warning margins in icing conditions.

2.2 Accident Sequence

2.2.1 Descent Into Icing Conditions

Surface observations and radar data indicated that freezing drizzle conditions existed in the PUB area around the time of the accident and that temperatures were below freezing from the surface to 30,000 feet. Several PIREPs and NWS products transmitted around the time of the accident, including winter weather advisories that warned of freezing drizzle, confirmed the presence of icing conditions in the PUB area. CVR evidence indicates that, starting about 0851, the flight crew began taking actions to minimize the icing's hazardous effects, such as activating the airplane's engine and windshield anti-ice systems. About 4 minutes later, the first officer stated that he saw a little bit of "grayish ice," which is indicative of ice that has a rough surface, building up on the wing leading edges. He then stated that there was "a real thin line back there."

An analysis of the CVR and meteorological information indicated that mixed icing conditions existed from about 21,000 to 14,000 feet. Radar data and CVR information indicated that the airplane was in this icing layer for about 5 1/2 minutes. At 0858:20, as the airplane was descending through about 18,000 feet, the first officer suggested to the captain that he might want to cycle the deice boots.[54] After cycling the deice boots, the captain indicated that the deice boots might have shed a little of the ice but that some ice remained on the wing, indicating the presence of residual ice.

2.2.2 Approach to Landing

In accordance with the SimuFlite Cessna Citation V Technical Manual and the Cessna Model 560 Citation V AFM, pilots were trained that, when any residual ice is present or can be expected during approach and landing, V_{ref} must be increased by 8 knots. The manuals also contained both a caution and a warning indicating that stall speeds increased during operations in icing conditions, and that, therefore, V_{ref} must be increased.

At 0859:29, the CVR recorded the first officer state that the V_{ref} was 96 knots. In the case of this flight, the V_{ref} should have been increased from 96 to 104 knots because of the icing conditions. The CVR did not record either pilot mention increasing the airspeed at any point during the approach. Therefore, the Safety Board concludes that the flight crew did not increase the V_{ref} while operating in icing conditions, contrary to company procedures and manufacturer guidance.

2.2.3 Final Approach

At 0908:25, while at an altitude of about 9,400 feet, the first officer reported that the flight was in IMC, and, about 1 minute later, while at an altitude of about 7,400 feet, he reported that clear ice had accumulated on the airplane's wing. CVR and meteorological information indicated that the airplane likely encountered SLD conditions from 9,400 to 6,100 feet (the calculated altitude at the time of the upset) and that the airplane was likely in these conditions for about 4 1/2 minutes. During this time, about 1 to 4 mm (0.039 to 0.156 inch) of additional ice could have accumulated on the wing leading edges. The Safety Board concludes that the airplane encountered SLD conditions, which are most conducive to the formation of thin, rough ice on or aft of the protected surfaces, during about the last 4 1/2 minutes of the flight. The Safety Board further concludes that the airplane had residual ice on the wings after the deice boots were activated earlier in the

[54] As noted, the pilots had been trained to wait until 1/4- to 1/2-inch-thick ice accumulation was visible on the wing leading edges before activating the deice boots.

flight and that this ice would have affected the overall thickness, roughness, and distribution of the SLD ice accumulation.

According to the airplane performance study, about 0910, the airplane started its final descent from 7,000 feet at an airspeed of about 155 knots. By about 0911:35, the airspeed had started to decrease. CVR evidence indicated that the landing gear was extended at 0911:10, followed by extension of the speedbrakes and selection of full flaps. At 0912:04, the first officer stated, “and you are plus twenty five,” to which the captain replied, “slowing.” On the basis of a V_{ref} of 96 knots, the airspeed would have been about 121 knots at the time of the first officer’s statement. At 0912:37, when the airplane was at an altitude of about 6,100 feet, the first officer told the captain that he might want to run the deice boots and that they had the V_{ref}.

Company procedures for approach and landing in icing conditions stated that, when reconfiguring for approach and landing (extending landing gear and selecting full flaps), pilots should activate the deice boot system when any ice accumulation, regardless of thickness, is visible on the wing leading edges and continue to monitor the leading edges for any reaccumulation. Although the CVR recorded the first officer mention to the captain that they might want to activate the deice boots at 0912:37, there is no evidence that the deice system was activated during the approach. Therefore, the Safety Board concludes that the flight crew did not activate the deice boots when configuring for the approach and landing, which was contrary to company procedures and manufacturer guidance.

The airplane performance calculations showed that, immediately after passing through about 6,100 feet, the airplane entered a large roll to the left concurrent with a sudden decrease in pitch, indicating the start of the loss of control and aerodynamic stall. No evidence exists indicating that the stall warning activated before or concurrent with the upset. In accordance with the Cessna Model 560 Citation V AFM and the design of the stall warning system, the accident airplane’s stall warning should have activated about 86 knots.

Although it could not be determined at precisely what airspeed the loss of control occurred, airplane performance calculations indicated that the stall occurred at an airspeed of about 90 knots, which was well above the expected stall speed in icing conditions of 81 knots. According to company and manufacturer guidance on approach airspeeds in icing conditions, the airplane’s airspeed at the time of the upset should have been about 114 knots.[55] The performance calculations and EGPWS ground speed data showed that the airspeed continued to decrease until the loss of control. The Safety Board concludes that the flight crew failed to maintain adequate airspeed during the final approach in icing conditions, which led to an aerodynamic stall from which they did not recover.

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[55] According to the guidance, the approach airspeed should be V_{ref}+10 knots, in this case, 106 knots. Because the guidance requires that 8 knots be added to the approach airspeed in icing conditions, the approach airspeed should have been 114 knots.

As noted, the flight crew did not increase the approach airspeed or activate the deice boots during the approach, which is required for the Cessna 560 when ice is present on the wing. Although it could not be determined precisely why the flight crew did not maintain adequate airspeed or activate the deice boots during the approach, the Safety Board discovered during the investigation that there may be insufficient training on operational procedures in icing conditions. For example, postaccident interviews with simulator flight instructors revealed that these procedures might not be getting emphasized during simulator training because the details of the training are left up to the individual instructors. Further, a review of two flight training centers' syllabuses revealed that they do not state that instructors should emphasize these procedures. The Board is concerned that these operational procedures are not being consistently evaluated during simulator training.

The Safety Board concludes that pilots could benefit from the reinforcement during training of the Cessna 560 AFM requirements to increase the airspeed and operate the deice boots during approaches when ice is present on the wings. Therefore, the Safety Board believes that the FAA should require that operational training in the Cessna 560 airplane emphasize the AFM requirements that pilots increase the airspeed and operate the deice boots during approaches when ice is present on the wings.

2.2.4 Flight Crew Monitoring and Workload Management

The Safety Board examined the flight crew's actions during the approach to determine the role of the timing of the approach briefing in the accident sequence. Although the flight crew had expected to land on runway 8L, based on the current ATIS information, at 0905:56, approach control issued vectors for the ILS to runway 26R. According to the CVR, the flight crew noted the change in the runway assignment and immediately tuned the radios and set the inbound course. However, subsequent discussion about the details of the runway 26R approach was not initiated until almost 5 minutes later, at 0910:47. During the remaining 2 minutes before the stall, the flight crew needed to intercept the localizer and glideslope and configure and slow the airplane for the approach. However, CVR evidence showed that, although these airplane-handling tasks were being performed, the flight crew was concurrently briefing the ILS 26R approach. Specifically, from 0912:17 to 0912:31, as the airspeed was decreasing, the flight crew briefed the missed approach procedure for runway 26R. It was only at the end of this discussion that the first officer recognized and called for the need to run the deice boots and indicated that the airplane had slowed to V_{ref}.

The Safety Board recognizes that a runway change can disrupt a flight crew's planning and may affect the pilots' ability to conduct an approach briefing during a relatively low workload phase of flight, such as the top of the descent. When the runway change occurs late in the approach, it is important for flight crews to determine how and when to conduct the briefing to ensure that the objectives of the briefing are achieved without compromising safety of flight.[56] For the accident flight crew, the runway change occurred early enough for the briefing to have been completed before the pilots began to configure and slow the airplane for final approach. Literature on monitoring emphasizes that cockpit workload should be distributed to minimize conflicting task demands during critical phases of flight. In this case, the flight crew's delayed approach briefing served to divert the pilots' attention from handling the airplane, managing the deice boot system, and monitoring the tasks that had to be performed during that period. The Safety Board concludes that the briefing conducted late in the approach was a distraction that impeded the flight crew's ability to monitor and maintain airspeed and manage the deice system.

The Safety Board has long recognized the importance of flight crew monitoring skills in accident prevention. For example, the Board's 1994 safety study of 37 major flight crew-involved accidents found that, for 31 of these accidents, inadequate monitoring and/or cross-checking had occurred.[57] The study found that flight crewmembers frequently failed to recognize and effectively draw attention to critical cues that led to the accident sequence. As a result of this safety study, the Board issued Safety Recommendations A-94-3 and -4 to the FAA concerning the need for enhanced training of pilot monitoring skills. The recommendations stated, in part, that the FAA should require airlines operating under 14 CFR Part 121 to provide line operational simulation training that "allows flightcrews to practice, under realistic conditions, non-flying pilot functions, including monitoring and challenging errors made by other crewmembers" and that airlines' initial operating experience programs should include training and experience for check airmen and pilots "in enhancing the monitoring and challenging functions."[58]

In response to these recommendations, the FAA upgraded its written guidance to industry to enhance pilot training on monitoring. Specifically, on September 8, 1995, the FAA revised AC 120-51, "Crew Resource Management Training," to emphasize monitoring issues. The guidance in AC 120-51 stated that "effective monitoring and cross-checking can be the last line of defense that prevents an accident" and that "the

[56] Industry guidance states that crews should ask ATC for assistance, such as requesting to receive delayed vectors or enter a holding pattern, when they become rushed or otherwise behind on their duties as a result of unanticipated routings.

[57] For additional information, see National Transportation Safety Board, *A Review of Flightcrew-Involved, Major Accidents of U.S. Carriers, 1978 through 1990*, Safety Study NTSB/SS-94/01 (Washington, DC: NTSB, 1994).

[58] The complete text of Safety Recommendation A-94-3 to the FAA was as follows: "Require U.S. air carriers operating under 14 CFR Part 121 to provide, for flight crews not covered by the Advanced Qualification Program, line operational simulation training during each initial or upgrade qualification into the flight engineer, first officer, and captain position that (1) allows flight crews to practice, under realistic conditions, non-flying pilot functions, including monitoring and challenging errors made by other crewmembers; (2) attunes flight crews to the hazards of tactical decision errors that are errors of omission, especially when those errors are not challenged; and (3) includes practice in monitoring and challenging errors during taxi operations, specifically with respect to minimizing procedural errors involving inadequately performed checklists." The complete text of Safety Recommendation A-94-4 to the FAA was as follows: "Require that U.S. air carriers operating under 14 CFR Part 121 structure their initial operating experience programs to include: (a) training for check airmen in enhancing the monitoring and challenging functions of captains and first officers; (b) sufficient experience for new first officers in performing the non-flying pilot role to establish a positive attitude toward monitoring and challenging errors made by the flying pilot; and (c) experience (during initial operating experience and annual line checks) for captains in giving and receiving challenges or errors." On January 19, 1996, the Safety Board classified these recommendations "Closed—Acceptable Alternate Action" in response to the FAA's upgrades of its training guidance.

monitoring function is always essential, particularly during approach and landing." Since that action, other FAA guidance on workload management and monitoring skills has been developed. For example, on February 27, 2003, the FAA expanded its guidance in this area in a revision of AC 120-71, "Standard Operating Procedures for Flight Deck Crewmembers," to emphasize the importance of procedures, such as distributing cockpit workload to avoid interfering with pilot monitoring and assigning cockpit responsibilities so that one pilot can monitor continuously during high workload periods. With respect to conducting approach briefings and their impact on monitoring, the AC states that pilots should "when able, brief the anticipated approach prior to top-of-descent" to allow "greater attention to be devoted to properly monitoring … because the crew is not having to divide attention between reviewing the approach and monitoring the descent." The guidance contained in both ACs is available to operators to support pilot training programs but is not mandatory.

The Safety Board is aware of recent accidents in which inadequate pilot monitoring was a causal or contributing factor to the accident and in which pilots on approach to landing failed to observe critical and salient cues.[59] These accidents demonstrate the importance of monitoring skills and effective workload management in ensuring safety of flight. Existing FAA guidance to operators addresses these skills but providing specific pilot training on effective monitoring and cockpit workload management would be a way for the aviation industry to effectively deliver and reinforce the importance of these skills to pilots. The Safety Board concludes that all operators would benefit from an increased focus on providing monitoring skills in their training programs, including those operating under 14 CFR Parts 121 and 135, as would pilots completing FAA-approved training programs for Part 91 operations.[60] Therefore, the Safety Board believes that the FAA should require pilot training programs be modified to contain modules that teach and emphasize monitoring skills and workload management and include opportunities to practice and demonstrate proficiency in these areas.

2.3 Deice Boot Systems

Company and manufacturer guidance states that the surface deice boots should be used when ice buildup is estimated to be between 1/4- to 1/2-inch thick and that "early activation of the boots may result in ice bridging on the wing." During the Comair

[59] For additional information, see National Transportation Safety Board, *Collision With Trees on Final Approach, Federal Express Flight 1478, Boeing 727-232, N497FE, Tallahassee, Florida, July 26, 2002*, Aviation Accident Report NTSB/AAR-04/02 (Washington, DC: NTSB, 2004); National Transportation Safety Board, *Crash During Approach to Landing, Air Tahoma, Inc., Flight 185, Convair 580, N586P, Covington, Kentucky, August 13, 2004*, Aviation Accident Report NTSB/AAR-06/03 (Washington, DC: NTSB, 2006); and National Transportation Safety Board, *Crash During Approach to Landing, Business Jet Services Ltd., Gulfstream G-1159A (G-III), N85VT, Houston, Texas, November 22, 2004*, Aviation Accident Brief NTSB/AAB-06/06 (Washington, DC: NTSB, 2006).

[60] The Safety Board recognizes that many pilots engaged primarily in noncommercial flying under 14 CFR Part 91 do not complete formal training programs but believes that these pilots can benefit from the increased industry emphasis and specific training principles on monitoring.

flight 3272 investigation, the Safety Board learned that many manufacturers and operators had similar deice boot operational guidance and concerns about ice bridging.

However, AC 25.1419-1A states that, although ice may not be completely shed by one cycle of the boots, the residual ice will usually be removed by subsequent cycles and does not act as a foundation for a bridge of ice to form. Further, information gathered at a 1997 Airplane Deice Boot Bridging Workshop, subsequent icing tunnel tests, and flight tests conducted as part of the Comair investigation revealed that ice bridging did not occur on modern airplanes, which are equipped with deice boots that quickly inflate and deflate. The icing tunnel tests also revealed that thin (1/4 inch or less), rough ice accumulations on the wing leading edge deice boot surfaces could be, depending on distribution, as aerodynamically detrimental to an airplane's performance as larger ice accumulations.

A search of the Safety Board accident database revealed no accidents related to ice bridging. Conversely, the Board has investigated many icing accidents in which the airplane stalled prematurely and the stall warning system did not activate before the stall because of ice accumulation on the wing leading edges. This accident, previous accident investigations, Safety Board accident data, and existing icing information clearly show that delaying the activation of the deice boots can create unsafe operations. The Safety Board concludes that ice bridging does not occur on modern airplanes; therefore, it is not a reason for pilots to delay activation of the deice boots.

As a result of its findings during the Comair flight 3272 investigation, the Safety Board issued Safety Recommendation A-98-91, which recommended that the FAA do the following:

> Require manufacturers and operators of modern turbopropeller-driven airplanes in which ice bridging is not a concern to review and revise the guidance contained in their manuals and training programs to emphasize that leading edge deicing boots should be activated as soon as the airplane enters icing conditions.

In May 2002, the FAA issued an icing test report that recommended an "early and often" approach to deice boot usage to limit the size of residual and intercycle ice accretions. Further, in January 2003, an ARAC IPHWG recommended revisions to Parts 25 and 121 to require that deice systems be activated as soon as an airplane enters icing conditions. However, since that time, the FAA has taken no action to issue a final rule adopting the regulatory changes proposed by the ARAC IPHWG.

Although the accident airplane most likely accumulated less than 1/4-inch-thick ice while operating in the lower cloud layer, the pilots' failure to activate the deice boots during the approach led to the continued accumulation of thin, rough ice on the protected surfaces, which can severely degrade an airplane's performance. The circumstances of this accident, information gathered during the Comair flight 3272 accident, and reports issued by the FAA and the ARAC IPHWG clearly demonstrate that existing guidance instructing pilots to delay activation of the deice boots until they observe 1/4- to 1/2-inch-thick ice accumulation is not adequate because it does not protect against the detrimental effects caused by thin, rough ice accumulation on or aft of the protected surfaces. If pilots continue to adhere to guidance about delaying deice boot activation, similar accidents could still occur.

The Safety Board concludes that activating the deice boots as soon as an airplane enters icing conditions provides the greatest safety measure. On the basis of this accident and the Board's continued concerns in this area, the Board believes that the FAA should require manufacturers and operators of pneumatic deice boot-equipped airplanes to revise the guidance contained in their manuals and training programs to emphasize that leading edge deice boots should be activated as soon as the airplane enters icing conditions. The new recommendation will supersede Safety Recommendation A-98-91 and will be classified "Open—Unacceptable Response."

The Safety Board is concerned that workload increases significantly when pilots of airplanes equipped with deice boots that do not cycle automatically operate in icing conditions because they must continuously monitor the ice accumulation on the airplane's surfaces and determine when to reactivate the deice boots. This consideration is consistent with FAA concerns in AC 23.1419-2C.[61] Having to operate the deice boot system manually is even more critical during the approach and landing phases of flight when pilot workload and monitoring demands are greatest.

The Safety Board concludes that manual operation of the deice boot system increases pilot workload, which can result in distraction during critical phases of flight, such as approach and landing. Therefore, the Safety Board believes that the FAA should require that all pneumatic deice boot-equipped airplanes certified to fly in known icing conditions have a mode incorporated in the deice boot system that will automatically continue to cycle the deice boots once the system has been activated.

2.4 Certification Requirements for Flight Into Icing Conditions

The Safety Board has previously identified concerns about inadequate flight test certification requirements. For example, the American Eagle flight 4184 accident investigation revealed that SLD conditions can cause ice accretions that are more aerodynamically detrimental than those accretions that fall within the Part 25, Appendix C envelope. As a result, the Safety Board issued Safety Recommendation A-96-54, which asked the FAA to do the following:

> Revise the icing criteria published in 14…CFR Parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the Appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary.

[61] AC 23.1419-2C stated that the effect on pilot workload of continuously cycling the deice boots should be evaluated.

Further, icing tunnel tests conducted as part of the Comair flight 3272 accident investigation indicated that the effects of ice accretion on airplane performance could vary widely depending on the size, distribution, and type of ice accumulated on the airplane's surfaces. However, the Board learned that manufacturers are not required to demonstrate an airplane's flight handling characteristics or stall margins using thin, rough ice that can accrete on protected surfaces before the activation of the deice boot system or between activation cycles. As a result of its findings, the Board issued Safety Recommendation A-98-92, which asked the FAA (in cooperation with NASA and other interested aviation organizations) to do the following:

> [C]onduct additional research to identify realistic ice accumulations and … determine the effects and criticality of such ice accumulations … the information developed … should be incorporated into aircraft certification requirements.

The Safety Board also issued Safety Recommendation A-98-100, which asked the FAA to review the icing certification of all turbopropeller-driven airplanes currently certificated for operation in icing conditions, perform additional testing, and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards asked for in Safety Recommendation A-98-92.

The FAA indicated in a March 6, 2006, response to Safety Recommendation A-96-54 that the ARAC IPHWG is continuing to develop a revision to Part 25 to require a demonstration that an airplane can safely operate in SLD conditions for an unrestricted time or can detect SLD and safely exit icing conditions. However, the FAA has still not received the recommendations from the IPHWG, prepared regulatory analyses, issued the NPRM, analyzed comments, or completed the many other tasks involved in issuing new regulations.

The FAA indicated in an October 26, 2005, response to Safety Recommendation A-98-92 that it had completed and would shortly issue a draft revision to AC 20-73, which included the certification guidance on determining critical ice shapes, descriptions of intercycle and residual ice accretions, and the aerodynamic penalties associated with these ice shapes. Although the FAA issued AC 20-73A on August 16, 2006, it has still not provided the Safety Board with information regarding any new research conducted in response to this recommendation.

Regarding Safety Recommendation A-98-100, the FAA issued an NPRM in November 2005, which proposed to expand 14 CFR Part 25 to include specific certification requirements for airplane performance or handling qualities for flight in icing conditions and to specify the ice accumulations that must be considered for each phase of flight. Further, the FAA proposed changes to AC 25-1X, which intended to provide guidance for implementing the regulations proposed in the NPRM.

In May 2006, the Safety Board expressed concern that, although it agreed with the proposed regulatory changes, the FAA had not applied the new standards to all in-service turbopropeller-driven aircraft. The FAA further indicated that no airplanes have an unsafe condition in icing environments despite a number of accidents in the 1990s that involved airplanes that had passed the certification standards. The Board stated that, to meet the intent of Safety Recommendation A-98-100, the FAA would need to formally evaluate (perhaps by conducting flight tests) all in-service turbopropeller-driven aircraft to ensure that these aircraft comply with all current icing certification criteria for new aircraft. The Board asked the FAA to provide a list of the aircraft that it had formally evaluated and a summary of the findings and resultant actions. To date, this information has not been received.

The circumstances of the Comair flight 3272, American Eagle 4184, and Pueblo accidents and the icing tunnel test data show that the ice shapes used during initial certification flight tests were not adequate because the tests did not account for thin, rough ice on the wing. The 1996 ice shapes tests on the Cessna 560 were also inadequate because, although tests were conducted with ice shapes on the protected surfaces, tests were not conducted using thin, rough ice. Therefore, additional ice sizes, distribution patterns, and types need to be considered during flight testing to more adequately gauge an airplane's performance in icing conditions.

The Safety Board concludes that existing flight test certification requirements for flight into icing conditions do not test the effects of thin, rough ice on or aft of an airplane's protected surfaces, which can cause severe aerodynamic penalties. The circumstances of this accident clearly show that the actions requested in Safety Recommendations A-96-54 and A-98-92 are needed to improve the safety of all airplanes operating in icing conditions. Therefore, the Safety Board reiterates Safety Recommendations A-96-54 and A-98-92. As noted, Safety Recommendation A-98-100 only addressed turbopropeller-driven airplanes.

The circumstances of this accident clearly demonstrate that deice boot-equipped turbojet airplanes also require additional testing in an expanded Appendix C icing certification envelope, which would include thin, rough ice accumulations and intercycle and residual ice. Therefore, the Safety Board believes that the FAA should, when the revised icing certification standards and criteria are complete, review the icing certification of all pneumatic deice boot-equipped airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards. The new recommendation (A-07-16) will supersede Safety Recommendation A-98-100 and will be classified "Open—Unacceptable Response."[62]

2.5 Inadequate Stall Warning Margins in Icing Conditions

Stall warning systems are intended to provide flight crews with adequate warning of an impending stall to give them enough time to take necessary action to prevent a stall.

[62] Safety Recommendation A-98-100 is on the Safety Board's List of Most Wanted Transportation Safety Improvements. Accordingly, Safety Recommendation A-07-16 will automatically be placed on the Most Wanted List.

The CVR sound spectrum study indicated that the accident airplane's stall warning did not activate until after the stall. The Pueblo accident is not the first accident in which a stall has occurred before the stall warning activated. For example, the Safety Board determined during the Comair flight 3272 accident investigation that the airplane departed controlled flight before the stall warning activated and that stall warning systems "often do not provide adequate warning when the airplane is operating in icing conditions."

As a result of the Comair investigation, the Safety Board issued Safety Recommendation A-98-96, which recommended that the FAA require manufacturers and operators of all airplanes certificated to operate in icing conditions to install stall warning systems that provide a cockpit warning before the onset of a stall when the airplane is operating in icing conditions. The FAA stated in an October 26, 2005, response letter that it was pursuing rule changes to require only that newly certificated airplanes have stall warning systems installed that provide a cockpit warning before the onset of a stall when operating in icing conditions and that it would take appropriate action on in-service airplanes only if an unsafe condition were identified.

The November 2005 NPRM proposed changes to 14 CFR 25.207 to require that only newly type-certificated airplanes be equipped with stall warning systems that provide a stall warning before the onset of a stall when the airplane is operating in icing conditions. In its comments on the proposed NPRM and in its May 2006 response letter to the FAA, the Safety Board stated that it was not acceptable for the FAA to wait until an accident or serious incident occurred to reveal that an unsafe condition existed on an in-service airplane and that, because the proposed changes did not address in-service airplanes, Safety Recommendation A-98-96 was classified "Open—Unacceptable Response." The Board continues to believe that not requiring in-service airplanes to be equipped with improved stall warning systems until an unsafe condition is identified is unacceptable and encourages the FAA to expedite issuance of a final rule that contains such a requirement.

Regarding the Cessna 560's stall warning system, in 1996, the FAA conducted ice testing using 1/2-inch ice shapes installed on the protected surfaces. As a result of these tests, in early 1999, Cessna began incorporating a modified stall warning system on Cessna 560 airplanes (including the accident airplane) to provide a 5-knot increase in the stall warning margin for operations in icing conditions. However, as this accident has shown, these modifications were not adequate because they did not take into account the effects of thin, rough ice on the protected surfaces; therefore, additional modifications to the airplane's stall warning system are necessary.

The Safety Board concludes that the Cessna 560 airplane's stall warning system did not provide a stall warning before the upset. The Safety Board further concludes that the Cessna 560 airplane's stall warning system does not provide a warning in all icing conditions, including those conditions in which thin, rough ice can accumulate on the protected surfaces. Therefore, the Safety Board believes that the FAA should require modification of the Cessna 560 airplane's stall warning system to provide a stall warning margin that takes into account the size, type, and distribution of ice, including thin, rough ice on or aft of the protected surfaces.

3. Conclusions

3.1 Findings

1. The captain and first officer were properly certificated and qualified under Federal regulations. No evidence indicated any preexisting medical or physical condition that might have adversely affected the flight crew's performance during the accident flight. A review of the pilots' 72-hour histories revealed that they slept well in the days leading up to the accident flight and went to bed early in preparation for an early departure. No evidence was found that fatigue degraded the performance of either pilot on the day of the accident.

2. The weight and balance of the airplane were within landing limits.

3. The recovered components showed no evidence of preexisting powerplant, structural, or system failures.

4. The Pueblo Memorial Airport local controller did not provide the accident flight crew or the Denver Flight Service Station with the pilot report reporting light to moderate icing; however, this was not a factor in the accident because cockpit voice recorder information indicated that the flight crew was aware of the icing conditions.

5. During the approach, the flight crew of the sister ship, which was following the accident flight, cycled the deice boots numerous times and maintained a high airspeed and, subsequently, landed safely, indicating the importance of taking these actions to counteract the hazardous effects of icing.

6. The flight crew did not increase the landing reference airspeed while operating in icing conditions, contrary to company procedures and manufacturer guidance.

7. The airplane encountered supercooled large droplet (SLD) conditions, which are most conducive to the formation of thin, rough ice on or aft of the protected surfaces, during about the last 4 1/2 minutes of the flight. Further, the airplane had residual ice on the wings after the deice boots were activated earlier in the flight, and this ice would have affected the overall thickness, roughness, and distribution of the SLD ice accumulation.

8. The flight crew did not activate the deice boots when configuring for the approach and landing, which was contrary to company procedures and manufacturer guidance.

9. The flight crew failed to maintain adequate airspeed during the final approach in icing conditions, which led to an aerodynamic stall from which they did not recover.

10. Pilots could benefit from the reinforcement during training of the Cessna Model 560 Citation V Airplane Flight Manual requirements to increase the airspeed and operate the deice boots during approaches when ice is present on the wings.

11. The briefing conducted late in the approach was a distraction that impeded the flight crew's ability to monitor and maintain airspeed and manage the deice system.

12. All operators would benefit from an increased focus on providing monitoring skills in their training programs, including those operating under 14 *Code of Federal Regulations* Parts 121 and 135, as would pilots completing Federal Aviation Administration-approved training programs for Part 91 operations.

13. Ice bridging does not occur on modern airplanes; therefore, it is not a reason for pilots to delay activation of the deice boots.

14. Activating the deice boots as soon as an airplane enters icing conditions provides the greatest safety measure.

15. Manual operation of the deice boot system increases pilot workload, which can result in distraction during critical phases of flight, such as approach and landing.

16. Existing flight test certification requirements for flight into icing conditions do not test the effects of thin, rough ice on or aft of an airplane's protected surfaces, which can cause severe aerodynamic penalties.

17. The Cessna 560 airplane's stall warning system did not provide a stall warning before the upset.

18. The Cessna 560 airplane's stall warning system does not provide a warning in all icing conditions, including those conditions in which thin, rough ice can accumulate on the protected surfaces.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to effectively monitor and maintain airspeed and comply with procedures for deice boot activation on the approach, which caused an aerodynamic stall from which they did not recover. Contributing to the accident was the Federal Aviation Administration's failure to establish adequate certification requirements for flight into icing conditions, which led to the inadequate stall warning margin provided by the airplane's stall warning system.

4. Safety Recommendations

4.1 New Safety Recommendations

As a result of its investigation of the February 16, 2005, accident involving a Cessna Citation 560, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Require that operational training in the Cessna 560 airplane emphasize the airplane flight manual requirements that pilots increase the airspeed and operate the deice boots during approaches when ice is present on the wings. (A-07-12)
>
> Require that all pilot training programs be modified to contain modules that teach and emphasize monitoring skills and workload management and include opportunities to practice and demonstrate proficiency in these areas. (A-07-13)
>
> Require manufacturers and operators of pneumatic deice boot-equipped airplanes to revise the guidance contained in their manuals and training programs to emphasize that leading edge deice boots should be activated as soon as the airplane enters icing conditions. (A-07-14) (This safety recommendation supersedes Safety Recommendation A-98-91[63] and is classified "Open—Unacceptable Response.")
>
> Require that all pneumatic deice boot-equipped airplanes certified to fly in known icing conditions have a mode incorporated in the deice boot system that will automatically continue to cycle the deice boots once the system has been activated. (A-07-15)
>
> When the revised icing certification standards (recommended in Safety Recommendations A-96-54 and A-98-92) and criteria are complete, review the icing certification of pneumatic deice boot-equipped airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards. (A-07-16) (This safety recommendation supersedes Safety Recommendation A-98-100[64] and is classified "Open—Unacceptable Response.")

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[63] For more information about this recommendation, see sections 1.18.2.1 and 2.3.

[64] For more information about this recommendation, see sections 1.18.2.2 and 2.4.

> Require modification of the Cessna 560 airplane's stall warning system to provide a stall warning margin that takes into account the size, type, and distribution of ice, including thin, rough ice on or aft of the protected surfaces. (A-07-17)

4.2 Previously Issued Safety Recommendations Reiterated in This Report

The Safety Board reiterates the following safety recommendations to the Federal Aviation Administration:

> Revise the icing criteria published in 14 *Code of Federal Regulations* Parts 23 and 25, in light of both recent research into aircraft ice accretion under varying conditions of liquid water content, drop size distribution, and temperature, and recent developments in both the design and use of aircraft. Also, expand the Appendix C icing certification envelope to include freezing drizzle/freezing rain and mixed water/ice crystal conditions, as necessary. (A-96-54)[65]

> With the National Aeronautics and Space Administration and other interested avation organizations, conduct additional research to identify realistic ice accumulations, to include intercycle and residual ice accumulations and ice accumulations on unprotected surfaces aft of the deicing boots, and to determine the effects and criticality of such ice accumulations; further, the information developed through such research should be incorporated into aircraft certification requirements and pilot training programs at all levels. (A-98-92)

For more information about these recommendations, see sections 1.18.2.2 and 2.4.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Chairman

ROBERT L. SUMWALT
Vice Chairman

DEBORAH A. P. HERSMAN
Member

KATHRYN O. HIGGINS
Member

STEVEN R. CHEALANDER
Member

Adopted: January 23, 2007

[65] Safety Recommendation A-96-54 superseded Safety Recommendation A-81-116, which was issued in 1981.

Board Member Statements

Member Deborah A.P. Hersman's Statement, Concurring in part and Dissenting in part:

While I agree with the general outcome of this report, I believe the probable cause ultimately approved by the Board is not entirely consistent with the rest of the report. As I asserted at the Board meeting on January 23, 2007, the inadequate guidance provided to aircraft operators regarding the operation of deice boots should have been cited as a contributing factor. Furthermore, the FAA's inadequate certification requirements for flight into icing conditions should have been cited as one of the two primary causes of the accident, rather than as a contributing cause.

The final probable cause would lead one to believe that this was not an icing accident but simply an accident of pilot failures—failure to effectively monitor and maintain airspeed and failure to properly activate the deice boots. However, the rest of the report lays a foundation for finding that this accident was very much about ice and a lack of understanding among operators about whether an aircraft can safely operate in any type of ice and how to appropriately manage ice accumulation.

FAA's failure to establish proper certification requirements for aircraft flying in icing conditions should be cited as one of the primary causes of this accident. The Board has long been concerned about aircraft icing and inadequate certification standards. Following the Safety Board's 1981 study on aircraft icing, numerous recommendations were issued to the FAA to revise certification standards regarding ice accretion under varying conditions. In over 25 years, the FAA has done little to address this issue and we have reiterated the original recommendations over and over and they remain on our Most Wanted List of Safety Improvements in an unacceptable status.

According to the Cessna Model 560 Citation V AFM, the airplane's anti-ice and de-ice systems were not designed to protect against freezing rain or severe conditions of mixed or clear ice. However, during the investigation of this accident, the National Center for Atmospheric Research determined that, on the basis of surface, radar, upper air, and satellite data, the airplane likely encountered Supercooled Large Droplet conditions, which are more conducive to the accumulation of thin, rough ice, between 9,400 to 6,100 feet (the altitude at which the upset occurred). The pilots were unaware that they were flying in conditions that the plane was not certificated for because there are no reliable methods for flight crews to differentiate, in flight, between water drop sizes that are outside the certification envelope. Furthermore, the Cessna 560 airplane's stall warning system does not provide warning in this type of icing condition.

In a recommendation in 1996, the Board recommended that FAA revise its icing criteria. That recommendation is being reiterated in this report. Another recommendation issued to FAA in 1996 is being revised and re-issued in this report, recommending that FAA revise icing certification requirements for airplanes equipped with pneumatic deice boots. Perhaps, if FAA had taken such measures 10 years ago, much more would have been understood by the pilots about flying in this type of icing condition. For that reason, FAA has a place in the probable cause equal to that of the pilots who executed the errors in the conduct of this flight.

The narrative of the accident is clear that the pilots of this aircraft did not fail to monitor the icing conditions. The cockpit voice recorder revealed that they were aware of the icing conditions and they activated the de-ice boots at least once. The First Officer talked about the color of the ice, the rate of accumulation, and compared it to the ice accumulated on the previous day, and the Captain discussed the ice remaining on the wings after the initial activation of the deice boots. The probable cause faults the crew, not because they did not *effectively* monitor the icing conditions, but because they failed to activate the deice boots at the correct time.

The report states that the manufacturer's guidance and language in the AFM recommends that the deice boots be used when the ice buildup is between ¼ to ½ inches thick and that early activation of the boots could result in ice bridging. Despite information revealed during previous NTSB accident investigations (Comair Flight 3272, Monroe, Michigan, January 9, 1997), NASA published research on the topic, public information events such as the November 1997 Airplane Deicing Boot Ice Bridging Workshop, and various FAA publications, the ice bridging concept is still real to some pilots and operators. This concern about ice bridging was reinforced to this Board Member during a conversation earlier this month, with a well-respected pilot of a modern Cessna aircraft equipped with pneumatic boots, who repeatedly spoke of ice bridging and the guidance from the manual requiring a ¼ to ½ inch of ice accumulation before activating the boots. Regrettably, it appears that little has changed in the 10 years since the Board investigated the Monroe accident, the following language was contained in our November 30, 1998, recommendation letter to Administrator Garvey on recommendations A-98-88 through –106:

> *"This illustrates how thoroughly ingrained the ice bridging concept was in pilots and operators and the importance of an ice bridging pilot education program. Therefore, a thin, yet performance-decreasing type of ice (similar to that likely accumulated by Comair flight 3272) can present a more hazardous situation that a 3-inch ram's horn ice accumulation because it would not necessarily prompt the activation of the boots. Based on this information, the Safety Board concludes that the current operating procedures recommending that pilots wait until ice accumulates to an observable thickness before activating leading edge deicing boots results in unnecessary exposure to a significant risk… Based primarily on concerns about ice bridging, pilots continue to use procedures and practices that increase the likelihood of (potentially hazardous) degraded airplane performance resulting from small amounts of rough ice accumulated on the leading edges."*

Yet in another part of the AFM, the direction to the crew is contradictory, "When configuring for approach and landing… with any ice accretion visible on the wing leading edge, regardless of thickness, activate the surface deice system. Continue to monitor the wing leading edge for any accumulation." Unfortunately, our investigators found that the SimuFlite training syllabus had no specific instruction to evaluate crew performance of the AFM procedures to increase the airspeed and operate the deice boots during approaches when ice is present on the wings. In addition, one of the instructors was unaware of these AFM procedures. Furthermore, this guidance about activating the deice boots on approach with any ice accretion seems to nullify the earlier guidance about waiting for a measurable ice build up prior to boot activation and de-bunking the myth of ice-bridging. Which leads me to question why Cessna requested, and the FAA agreed to withdraw NPRM 99-NM-136-AD, which was applicable to Cessna model 500, 501, 550, 551, and 560 series airplanes and proposed revising the applicable AFMs to include a requirement to activate the deice boots at the first sign of ice accumulation and to cycle the boots to minimize ice accumulation. When the NPRM was withdrawn, Cessna continued to publish the ¼ to ½ inch accumulation language. If it is safer to eliminate any visible ice from the wings during the approach phase of flight, then the same logic ought to apply to all phases of flight.

FAA Advisory Circular AC 25.1419-1A states that residual ice does not act as a foundation for bridging ice. Furthermore, our report states, additional tests have shown that ice bridging does not occur on modern airplanes and deice boots should be activated as soon as an aircraft enters icing conditions. This contradiction between recent studies, the FAA Advisory Circular, and manufacturer guidance led the Board to include in this report a recommendation that FAA require manufacturers and operators of airplanes with deice boots to *revise the guidance* in their manuals to emphasize that deice boots should be activated as soon as the airplane enters icing conditions. Furthermore, the Board reiterated an older recommendation that FAA conduct additional research on the effects of residual ice accumulations behind the deicing boots and incorporate those new findings into the certification requirements and pilot training programs.

I believe that in failing to cite the inadequate guidance as a contributing factor in the probable cause, and in relegating FAA's failures to only a contributing cause, the Board is leaving a part of this investigation report undone. In our quest to make flying ever safer, we may never reach a time when pilots don't sometimes make inexplicable errors. But in a case such as this one where we can piece the evidence together and spot plausible reasons *why* the pilots made the mistakes they made, we should do so emphatically. In almost 40 years of accident investigations, we have improved aviation safety and improved our process of accident investigations, but I believe we can and should reach further in our efforts. Simply citing the flight crew's failure to monitor and maintain airspeed and de-ice the wings as required by the AFM is not going far enough. Until the AFMs fly the airplanes, we need to address the actions of the human beings who do fly the airplanes. In this accident, the reason the pilots failed in their critical tasks is because they did not have the benefit of proper guidance from the FAA and from the manufacturer about flying in the conditions they found themselves. While the Board articulated this issue very clearly in our conclusions and our recommendations, I believe the Board should have included this aspect in the probable cause as the best means of helping to prevent other pilots from making the same error in the future.

Member Higgins joined Member Hersman in this statement.

[Original signed]

Deborah A. P. Hersman
January 30, 2007

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5. Appendixes

Appendix A
Investigation and Public Hearing

Investigation

The National Transportation Safety Board was initially notified about this accident on the afternoon of February 16, 2005. A full go-team was assembled in Washington, D.C., and traveled to the accident scene. The go-team was accompanied by former Chairman Engleman Conners.

The following investigative groups were formed: Operations, Meteorology, Air Traffic Control, Airworthiness, Maintenance Records, Powerplants, Aircraft Performance, Survival Factors, and Cockpit Voice Recorder.

Parties to the investigation were the Federal Aviation Administration; Martinair, Inc.; and Cessna Aircraft Company. An accredited representative from the Transportation Safety Board of Canada and a technical advisor from Pratt and Whitney Canada also assisted in the investigation.

Public Hearing

No public hearing was held for this accident.

Appendix B
Cockpit Voice Recorder Transcript

The following is the transcript of the B&D Instruments and Avionics cockpit voice recorder, serial number A01148, installed on a Cessna 560 that crashed while on approach to Pueblo Memorial Airport, Pueblo, Colorado, on February 16, 2005.

LEGEND	
HOT	Crewmember hot microphone voice or sound source
RDO	Radio transmission from accident aircraft
CTR1	Radio transmission from 1st Denver Center controller
CTR2	Radio transmission from 2nd Denver Center controller
APR	Radio transmission from Pueblo approach control
FBO	Radio transmission from Pueblo fixed base operator
TWR	Radio transmission from Pueblo tower
TWR	Radio transmission from aircraft N500FK
SW6431	Radio transmission from Skywest flight six four three one
-1	Voice identified as Pilot-in-Command (PIC)
-2	Voice identified as Co-Pilot (SIC)
-3	Voice identified as aircraft mechanical voice
-?	Voice unidentified
*****	Unintelligible word
@	Non-pertinent word
#	Expletive
- - -	Break in continuity
( )	Questionable insertion
[ ]	Editorial insertion
...	Pause

Note 1: Times are expressed in mountain standard time (MST).

Note 2: For ATC transmissions, generally only radio transmissions to and from the accident aircraft were transcribed.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0841:19 **START of RECORDING** **START of TRANSCRIPT**			
0842:27 **HOT-2**	the secondary held in there pretty good on that little bit of descent.		
0842:30 **HOT-1**	yeah.		
0842:32 **HOT-2**	called standby I guess they call it.		
0842:35 **HOT-1**	twenty feet.		
0843:50 **HOT-2**	one thing I was thinking about, I'm surprised that Jepps didn't show that, as good as Jepps is.		
0843:59 **HOT-1**	yeah, I would have thought it would have been on there.		
0844:01 **HOT-2**	I mean that's not your every day departure procedure if you're an east coast flier.		
0844:03 **HOT-1**	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0844:21 **CTR1**	Citation five hundred Alpha Tango, descend and maintain flight level two seven zero.
		0844:25 **RDO-2**	five hundred Alpha Tango, three six oh for two seven oh.
0844:31 **HOT-1**	twenty seven.		
0844:32 **HOT-2**	twenty seven.		
0844:50 **HOT-2**	uh, no arrivals or nothing. they do have a uh, a radar, ASR if we had to have it. that's old as #. I reckon it's still in use.		
0845:00 **HOT-1**	yeah.		
		0845:43 **500FK**	Denver, good morning, Citation five zero zero Fox Kilo's with you out of thirty five and a half down to three four zero.
		0845:49 **CTR1**	Citation five zero zero Foxtrot Kilo Denver center, roger.
0846:06 **HOT-2**	did you got number, well number one for me.		
0846:07 **HOT-1**	I got one.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0846:13 **RDO-2**	Flower Aviation, Pueblo, Citation five hundred Alpha Tango.
		0846:20 **FBO**	good morning five hundred Alpha Tango, this is Flower Aviation in Pueblo, go ahead.
		0846:25 **RDO-2**	yes ma'am, how you doing this morning? we'll be landing in about twenty minutes and we have uh, six passengers. be a uh, pit stop and a quick turn. and, gonna give you a fuel (order) here in just a second.
		0846:43 **FBO**	I understand that you're twenty minutes out. you have six passengers for a pit stop and a quick turn and you'll give me the fuel in just a minute.
0846:51 **HOT-2**	you still want, you still want two hundred?		
0846:54 **HOT-1**	uuh, yeah uh, have you already talked to 'em?		
0846:58 **HOT-2**	no, I've got her on the radio.		
0847:00 **HOT-1**	let's make it two ten a side.		
0847:01 **HOT-2**	okay. that sounds good.		

INTRA-COCKPIT COMMUNICATION TIME (MST) & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME (MST) & SOURCE	CONTENT
		0847:06 **RDO-2**	and uh, young lady there at Flower Aviation for five hundred Alpha Tango. we'll take two hundred and ten gallons a side, with Prist.
		0847:16 **FBO**	I understand that you're gonna want two one zero, two hundred and ten gallons a side and our Jet A is pre-mixed.
		0847:23 **RDO-2**	okeydoke, and we'll, and we'll see you in just a little bit for the quick turn. and we have uh, just to let you know, we got company traffic behind us uh, about ten minutes too.
		0847:24 **CTR1**	Citation five hundred Alpha Tango contact Denver center one three three point four.
		0847:28 **RDO-1**	thirty three four uh, Alpha Tango, so long.
		0847:31 **FBO**	okay, we'll see you in twenty minutes on the west end of the main terminal and we'll see your company in thirty minutes on the west end of the main terminal.
		0847:39 **RDO-2**	okeydoke, thank you.
		0847:40 **RDO-1**	and Denver center, Citation five hundred Alpha Tango's with you checking in three two zero for two seven zero.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0847:48 **CTR2**	Citation five hundred Alpha Tango Denver center, cross uh, change that to just descend and maintain one three, thirteen thousand. the Pueblo altimeter's three zero one six.
		0847:57 **RDO-1**	thirty sixteen and one three thousand uh, Alpha Tango.
0848:02 **HOT-2**	all right, I'm back with you.		
0848:04 **HOT-1**	all right.		
0848:06 **HOT-2**	uh, down to thirteen thousand.		
0848:07 **HOT-1**	I see that.		
0848:08 **HOT-2**	uh.... what'd he say? three zero one six?		
0848:14 **HOT-1**	think that's what he said.		
0848:16 **HOT-2**	yeah, that's what I got. she says she'll be waiting at the main ramp.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0848:23 **HOT-1**	okay. I wonder what that means, she'll be waiting at the main ramp?		
0848:37 **HOT-2**	the, the fueler will.		
0848:38 **HOT-1**	uh, okay.		
0848:41 **HOT-2**	I, I, I think, I think it's just one ramp there.		
0848:42 **HOT-1**	okay.		
0848:48 **HOT-2**	it appears, I think, I didn't quite understand kinda staticy, but she said they'd be waiting.		
0850:47 **HOT-1**	okay.		
0851:30 **HOT-1**	* interesting, I wonder how we got on heading?		
0850:40 **HOT-1**	*, I'm gonna heat 'em up.		
0850:48 **HOT-2**	all righty, sounds good.... you get these kind of descents out here too. just come right on down....		
0850:48 **HOT-1**	yeah.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0851:17 **HOT-2**	... don't worry about all this leveling off stuff.		
0851:23 **HOT-2**	I don't know how far out? seventeen miles seems like a long ways. uh, usually they do about ten, don't they?		
0851:25 **HOT-1**	yeah.		
0851:33 **HOT-2**	I don't know if there's a reason for that, but uh.... or it shows a procedure turn. they may bring you in right to the uh....		
0851:36 **HOT-1**	well, they've got approach control there don't they?		
0851:38 **HOT-2**	yeah, we got Pueblo approach.		
0851:39 **HOT-1**	yeah, they'll probably give us just radar vectors.		
0852:18 **HOT-2**	now if you were on one engine, and you wanted to....		
		0852:21 **500FK**	Denver, five hundred Fox Kilo's uh, with you descending to two seven zero.
0852:24 **HOT-2**	...heat that thing up. heat both edges. you would put your engine anti-ice switch down….		

INTRA-COCKPIT COMMUNICATION TIME (MST) & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME (MST) & SOURCE	CONTENT
		0852:26 **CTR2**	five hundred Foxtrot Kilo, Denver Center roger and uh, cleared to descend and *** descend and maintain one three, one three thousand. the uh, Pueblo altimeter is three zero one six.
0852:29 **HOT-1**	yeah transfer yeah....		
0852:29 **HOT-2**	on the engine that's running and that.....		
0852:31 **HOT-1**	...would then heat the opposite side.		
0852:32 **HOT-2**	that would bleed both of 'em.		
0852:33 **HOT-1**	yeah.		
		0852:39 **500FK**	thirty sixteen. down to one three thousand. Foxtrot Kilo.
0852:39 **HOT-1**	I guess I'm trying to remember is the two that way.		
0852:40 **HOT-2**	no.		
0852:41 **HOT-1**	no?		
0852:42 **HOT-2**	no. it does not have cr... 'cause it's electric.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0852:45 **HOT-1**	that's right, that's right.		
0852:46 **HOT-2**	the, the front of the wing is electric.		
0852:57 **HOT-2**	and why would you need the heat on a dead engine, just to keep the ice from flying back into it?		
0853:02 **HOT-1**	yeah. yeah, just keeps everything clean.		
0853:10 **HOT-2**	oh, not so much engine protection, just the wing....		
0853:11 **HOT-1**	it's the wing yeah.		
0853:13 **HOT-2**	...itself.		
0853:14 **HOT-1**	aah.		
0853:17 **HOT-2**	you want me to ask them if we can slow down a little bit?		
0853:19 **HOT-1**	yeah.		
0853:57 **HOT-2**	they got the white knuckle guy on the other airplane, right?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0854:00 **HOT-1**	yeah. oh, ** I don't know if any of these are or not but I know that @ is on theirs.		
0854:16 **HOT-1**	all right, windshield heat's comin' on.		
0854:18 **HOT-2**	okay.		
0854:19 **HOT-1**	you got 'em cracked.		
0854:24 **HOT-2**	yeah.		
0854:35 **HOT-1**	I really can't see lookin' into the sun. you'll have to let me know if you see anything.		
0854:39 **HOT-2**	okay, it's building a little bit right on the leading edge.		
0854:43 **HOT-1**	all right.		
0855:07 **HOT-2**	it's not the real white ice like we had yesterday. it's more of a grayish.		
0855:10 **HOT-1**	all right.		
0856:18 **HOT-2**	there's a real thin line back there.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	CONTENT	TIME (MST) & SOURCE	CONTENT
0856:19 **HOT-1**	okay, I can see now yeah. couldn't see b', when on top of those clouds, so bright.		
0856:39 **HOT-2**	and, just a little positional awareness, that's direct to Pueblo there too.		
0856:44 **HOT-1**	all right.		
0856:46 **HOT-2**	anything west of it, the terrain starts rising.		
0857:13 **HOT-1**	uh, too bad it's not a clear day, it'd be right pretty.		
0857:16 **HOT-2**	yeah, I imagine it would.		
0858:00 **HOT-2**	uh, one eight oh, three zero one six.		
0858:03 **HOT-1**	sixteen is set twice. recogs are coming on.		
0858:05 **HOT-2**	all right. transition check complete.		
0858:15 **HOT-1**	uh, doesn't look like we picked up any more.		
0858:17 **HOT-2**	nope.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	CONTENT	TIME (MST) & SOURCE	CONTENT
0858:20 **HOT-2**	I don't know if you want to cycle it one time. it ain't gonna, at minus three it ain't gonna melt much on the ground.		
0858:25 **HOT-1**	naw, it isn't.... might've gotten rid of a little but not much.		
0858:45 **HOT-2**	little sticky ice today.		
0858:46 **HOT-1**	yeah.		
0858:58 **HOT-2**	okay belts and harness, good on my side.		
0859:00 **HOT-1**	good on the left.		
0859:02 **HOT-2**	passenger seats. everybody still looks okay. exits are clear. avionics, flight instruments. I've got Pueblo on hold. localizer, one oh nine five and we set the inbound oh seven seven.		
0859:15 **HOT-1**	set up.		
0859:17 **HOT-2**	crossfeed?		
0859:17 **HOT-1**	is normal.		
0859:18 **HOT-2**	passenger lights are on. anti-skids?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0859:20 **HOT-1**	is on.		
0859:23 **HOT-2**	ground idle?		
0859:24 **HOT-1**	is normal.		
0859:25 **HOT-2**	I'll hold there on the sync.		
0859:28 **HOT-1**	all righty.		
0859:29 **HOT-2**	ninety six on your ref.		
0859:32 **HOT-1**	that's set.		
0859:32 **HOT-2**	and crew brief we've talked about. I'll hold right there.		
0859:53 **HOT-2**	the descent accumulation comes a little bit different than the climb accumulation.		
0859:57 **HOT-1**	yeah. a whole lot faster in the descent than in the climb.		
		0900:30 **RDO**	[sound Morse code identification similar to pilot identifying navigation station]

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0901:09 **HOT-2**	yeah I bet this would be really pretty if it was clear.		
0901:11 **HOT-1**	oh yeah.		
0901:23 **HOT-2**	so Pueblo's just a little south of Denver still on the east side of the front range.		
0901:27 **HOT-1**	yeah, yeah and it's south also of uh, of Colorado Springs....		
0901:32 **HOT-2**	uh huh.		
0901:32 **CAM**	[sound similar to altitude alerter]		
0901:33 **HOT-1**	...Colorado Springs sits in the middle, one to go.		
0901:38 **HOT-2**	one to go. got clear air for a little bit.		
0902:14 **HOT-2**	this is kinda equivalent of being down to eight thousand to hand off to Potomac.		
0902:20 **HOT-1**	yeah.		
0902:52 **HOT-1**	just leave the heats on.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0902:55 **HOT-2**	okay. got everything nice and warmed up.		
0903:01 **HOT-1**	yeah.		
0903:08 **HOT-1**	yeah, there's uh....		
0903:09 **HOT-2**	am I seeing clouds or am I possibly seeing Pikes Peak?		
0903:12 **HOT-1**	eeeh, that's probably Pikes Peak.		
0903:14 **HOT-2**	all that range.		
0903:15 **HOT-1**	yeah, well they're clouds I think behind it, but uh, I think what you're seeing on this side of it, the dark ridges, that's, that's the mountains. it looks like it could be clouds on the uh, west side of that, though.		
0903:36 **HOT-2**	very deceiving illusional up here with the clouds an....		
0903:37 **HOT-1**	yeah.		
0903:38 **HOT-2**	...when they slope and everything.		
0903:50 **HOT-2**	I got one little static wick back there on the aileron just....		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0903:54 **HOT-1**	vibrating.		
0903:55 **HOT-2**	...flapping like devil. the three right beside it are dead still.		
0904:02 **HOT-1**	the one that's vibrating, is it out on the tip?		
0904:04 **HOT-2**	nope. in, inboard of the aileron.		
0904:07 **HOT-1**	okay.		
0905:24 **HOT-2**	seems like they should be handing us down to the approach, huh?		
0905:26 **HOT-1**	yeah, you might want to check with 'em.		
0905:30 **HOT-2**	only thing is we got to go past * a little.		
		0905:32 **CTR2**	Citation zero Alpha Tango, contact Pueblo approach one two zero point one. we'll see you.
		0905:39 **RDO-2**	okay, one twenty dot one and we'll see you in just a little bit.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0905:43 **CTR2**	all right.
		0905:50 **RDO-2**	and Pueblo approach, Citation five hundred Alpha Tango thirteen thousand with Juliet.
		0905:56 **APR**	Citation five hundred Alpha Tango, Pueblo approach. fly heading two four zero vectors ILS runway two six right final approach course. descend and maintain seven thousand.
		0906:05 **RDO-2**	'kay, two four zero on the heading and down to seven thousand and did you say two six right now?
		0906:13 **APR**	Citation zero Alpha Tango, affirmative, runway two six right for the ILS. traffic holding over the airport is a regional jet at niner thousand. report if you get him in sight.
		0906:23 **RDO-2**	okay, I'll be looking and uh, looking for the ILS two six right.
0906:27 **HOT-2**	changed up on us.		
0906:28 **HOT-1**	yeah.		
0906:29 **HOT-2**	he did a change on us here.		
0906:30 **HOT-1**	yeah, yeah.		

INTRA-COCKPIT COMMUNICATION | **AIR-GROUND COMMUNICATION**

TIME (MST) & SOURCE	CONTENT	TIME (MST) & SOURCE	CONTENT
0906:40 **HOT-2**	'kay, one oh eight point three.... inbound's gonna be a little bit different this time.		
0906:51 **HOT-1**	right.		
0906:52 **HOT-2**	it's gonna be inbound two five seven.		
0906:54 **HOT-1**	all right. two five seven. you still holding Pueblo?		
0906:58 **HOT-2**	I'm still holding Pueblo.		
0906:59 **HOT-1**	all right.		
0907:00 **HOT-2**	two five seven. the regional is holding.		
0907:02 **HOT-1**	all right.		
0907:03 **HOT-2**	do you want me to ask him if he is holding for, or is he climbing out or is....		
0907:05 **HOT-1**	I, I....		
0907:07 **HOT-2**	...holding for the missed?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0907:07 **HOT-1**	I suspect, oh no, it couldn't be for a miss. I'm sure he, he's either climbing out or.... I mean you can ask him but uh, he didn't say anything about us to expect any holding.		
		0907:30 **RDO-2**	and Pueblo, just a little heads up for Alpha Tango. is a holding expected or is that fellow climbing out in a holding pattern?
		0907:36 **APR**	Citation zero Alpha Tango, that aircraft is holding in the uh, traffic uh, pattern. he needs to burn off some fuel. do you have him in sight, twelve o'clock and uh, one zero miles?
0907:46 **HOT-1**	naw.		
		0907:47 **RDO-2**	uh, no sir. what's his altitude?
		0907:51 **APR**	roger, he's holding at niner thousand. why don't you go ahead and uh, give me a best rate of descent through niner thousand or maintain one zero thousand. I'll just turn you.
		0908:01 **RDO-2**	okay, we'll head on down to seven thousand and through nine.
0908:05 **HOT-2**	so we don't have....		
		0908:06 **APR**	Citation zero Alpha Tango roger, that traffic eleven moving twelve o'clock and niner miles turning northbound at niner thousand.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0908:14 **RDO-2**	okay, we're out of ten now hurrying on down to seven. he must be IMC.
		0908:20 **APR**	negative, he's just on top.
0908:24 **HOT-1**	aah, we're well....		
		0908:25 **RDO-2**	okay but we're IMC now at ninety four hundred ah, Alpha Tango.
		0908:29 **APR**	Citation zero Alpha Tango roger. turn left heading of one seven zero.
		0908:35 **RDO-2**	left turn one seven zero, Alpha Tango.
		0908:40 **APR**	Skywest sixty four thirty one, are you IMC?
		0908:43 **SW6431**	yeah, we're just at the top here. it's pretty darn hazy though. get-tin' a little ice here and there. and uh, we have them on TCAS. ** passing behind us now.
		0908:49 **APR**	regional jet or correction Skywest sixty four thirty one, Roger.
0908:55 **HOT-2**	all right, comin' up on, one to go.		

INTRA-COCKPIT COMMUNICATION TIME (MST) & SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME (MST) & SOURCE	CONTENT
		0908:55 **APR**	Citation zero Alpha Tango, turn right heading of two niner zero intercept the localizer inbound. traffic five miles....
0909:02 **CAM**	[sound similar to altitude alert signal]		
		0909:03 **APR**	...west your position level at niner thousand. maintain seven thousand until established, you're cleared approach.
		0909:07 **RDO-2**	okay, that's a right turn to two niner zero to intercept and cleared for the approach uh, five hundred Alpha Tango at seven thousand.
		0909:16 **APR**	Citation zero Alpha Tango, affirmative.
0909:19 **HOT-2**	you got a little different ice on there now. it's clear.		
0909:22 **HOT-1**	yeah.		
0909:26 **HOT-1**	and open up those valves all the way.		
0909:28 **HOT-2**	all right, will do.... okay, you're cleared for the approach. do you want the uh....		
0909:38 **HOT-1**	yeah, I want to keep that out 'til we slow down and we can get some flaps out.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0909:41 **APR**	Citation zero Alpha Tango, measured ceiling niner hundred broken, one thousand four hundred overcast. visibility six, mist. temperature minus three, dew point minus four. wind currently zero seven zero at seven. and altimeter's three zero one six.
		0909:59 **RDO-2**	okay, copy that on the weather for Alpha Tango.
0910:03 **HOT-1**	we're cleared, we're cleared for the approach?		
0910:05 **HOT-2**	yeah, we have been.		
		0910:08 **RDO-2**	Alpha Tango, just want to verify. we are cleared for the approach.
		0910:11 **APR**	Citation zero Alpha Tango, affirmative you are cleared approach.
0910:22 **HOT-2**	'kay, ignition is on with the anti-ice, now it's on for sure. glideslope is alive.		
		0910:30 **500FK**	five hundred Fox Kilo's uh, with you, one three thousand, Juliet.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	CONTENT	TIME (MST) & SOURCE	CONTENT
		0910:35 **APR**	Citation five hundred Foxtrot Kilo, Pueblo approach. descend and maintain eight thousand. expect ILS runway two six right final approach course. reduce your speed to two one zero knots and then descend and maintain uh, seven thousand or correction eight thousand.
0910:47 **HOT-2**	it's two hundred decision height and three quarters of a mile.		
		0910:47 **500FK**	back to two ten, down to eight thousand and uh, are you aware Juliet's advertising the eight left ILS?
0910:51 **HOT-1**	all right.		
		0910:55 **APR**	affirmative, just kinda trying to save you a little bit of flight time. if you'd like runway eight left, I can certainly provide that.
		0911:01 **500FK**	no that's fine. we were just double checking you knew what was going on here and we're down to uh, eight thousand now and two hundred and ten knots for Alpha Tango.
0911:06 **HOT-2**	localizer's got it.		
0911:09 **CAM**	[sound of tone]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0911:09 **APR**	Citation zero Foxtrot uh....
0911:10 **HOT-1**	all right, gear's coming down.		
0911:12 **HOT-2**	there's your gear.		
		0911:13 **APR**	...or correction uh, Cita, correction Citation zero Alpha Tango, you're cleared approach. just remain with me runway two six right. cleared to land.
		0911:19 **RDO-2**	okay, five hundred Alpha Tango, cleared to land with you, at seven thousand. intercepting the glide slope.
		0911:26 **APR**	Citation zero Foxtrot Kilo, intercept the localizer inbound your present heading. maintain seven thousand 'til established. you're cleared ILS runway two six right approach.
0911:27 **HOT-1**	all right, this, this time it'll be what a, left turn off, or right turn off. uuuuuh. left turn off.		
0911:34 **HOT-2**	two six'll be a left turn off Hotel or Fox.		
0911:37 **HOT-1**	all right, all right.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
		0911:37 **500FK**	'kay uh, we are cleared for the approach now for five hundred Foxtrot Kilo.
0911:44 **CAM**	[sound similar to altitude alerter]		
0911:45 **HOT-1**	and speed brakes coming back out again.		
0911:46 **HOT-2**	okay. and standing, there's your glide slope intercept.		
0911:48 **HOT-1**	full flaps.		
0911:49 **HOT-2**	full flaps, here we go.		
		0911:53 **APR**	Citation zero Foxtrot Kilo, you picking up the localizer okay?
		0911:57 **500FK**	uh, yes sir. we're coming left to intercept it a little bit and we'll be right on it here in a second.
0912:00 **HOT-2**	full, full selected and indicated.		
0912:01 **HOT-1**	all right.		
0912:04 **HOT-2**	and you are plus twenty five.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0912:07 **HOT-1**	slowing.		
0912:08 **HOT-2**	slowing, sinking seven. captured the localizer and the glideslope. I've got some ground but stay on them gauges.		
0912:16 **HOT-1**	all right.		
0912:17 **HOT-2**	just a brief on the missed if we have to. it's climb to seven thousand, direct to the Pueblo localizer.		
0912:23 **HOT-1**	all right.		
0912:24 **HOT-2**	uh, Pueblo outer marker.		
0912:28 **HOT-1**	right turn or left turn?		
0912:29 **HOT-2**	it doesn't say. it says direct to it uh....		
0912:30 **HOT-1**	all right.		
0912:31 **HOT-2**	...straight ahead on the other side.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (MST) & SOURCE	**CONTENT**	**TIME (MST) & SOURCE**	**CONTENT**
0912:37 **HOT-2**	I don't know if you want to run your ice a little bit. you got the, Vref there.		
		0912:40 **APR**	Citation Foxtrot Kilo uh, traffic....
0912:42 **CAM**	[sound of high pitch tone for one second]		
0912:44 **HOT-1**	#.		
0912:46 **CAM-3**	bank angle, bank angle... bank angle.		
0912:49 **HOT-1**	oh #.		
0912:50 **HOT-1**	[groaning sound to end of recording]		
0912:55 **END of RECORDING** **END of TRANSCRIPT**			

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