Crash During Approach to Landing
Empire Airlines Flight 8284
Avions de Transport Régional
Aerospatiale Alenia ATR 42-320, N902FX
Lubbock, Texas
January 27, 2009

Accident Report

NTSB/AAR-11/02
PB2011-910402

National
Transportation
Safety Board

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490 L'Enfant Plaza, S.W.
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National Transportation Safety Board. 2011. ***Crash During Approach to Landing, Empire Airlines Flight 8284, Avions de Transport Régional Aerospatiale Alenia ATR 42-320, N902FX, Lubbock, Texas, January 27, 2009.*** **Aircraft Accident Report NTSB/AAR-11/02. Washington, DC.**

Abstract: This accident report discusses the January 27, 2009, accident involving Empire Airlines flight 8284, an Avions de Transport Régional Aerospatiale Alenia ATR 42-320, N902FX, which crashed short of the runway at Lubbock Preston Smith International Airport, Lubbock, Texas. The captain sustained serious injuries, and the first officer sustained minor injuries. The airplane was substantially damaged. The airplane was registered to FedEx Corporation and operated by Empire Airlines, Inc., as a 14 *Code of Federal Regulations* Part 121 supplemental cargo flight. Instrument meteorological conditions prevailed, and an instrument flight rules flight plan was filed. The safety issues discussed in this report include the flight crew's actions in response to the flap anomaly, the continuation of the unstabilized approach, the dispatch of the flight into freezing drizzle conditions, the efficiency of the emergency response, and simulator-based training for pilots who fly in icing conditions. Nine safety recommendations are addressed to the Federal Aviation Administration.

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Abbreviations and Acronyms

AAS	anti-icing advisory system
AC	advisory circular
AD	airworthiness directive
ADP	aircraft deicing program
ADU	advisory display unit
AEP	airport emergency plan
AFFF	aqueous film forming foam
AFM	airplane flight manual
AFW	Fort Worth Alliance Airport
agl	above ground level
AIM	Aeronautical Information Manual
AIRMET	airmen’s meteorological information
AOA	angle of attack
APM	aircraft performance monitoring
ARAC	Aviation Rulemaking Advisory Committee
ARFF	aircraft rescue and firefighting
ATC	air traffic control
ATCT	air traffic control tower
ATOS	air transportation oversight system
ATR	Avions de Transport Régional
ATR 42	Aerospatiale Alenia ATR 42-320
BEA	Bureau d’Enquêtes et d’Analyses
CFR	Code of Federal Regulations

CG	center of gravity
CRM	crew resource management
CVR	cockpit voice recorder
DGAC	Direction Générale de l'Aviation Civile
EADI	electronic attitude direction indicator
EASA	European Aviation Safety Agency
EFS	engineering flight simulator
ELP	El Paso International Airport
EMS	emergency medical service
FAA	Federal Aviation Administration
FAF	final approach fix
FCOM	flight crew operating manual
FDR	flight data recorder
FedEx	FedEx Corporation
FL	flight level
fpm	feet per minute
FR	Federal Register
FSDO	flight standards district office
FSIB	flight standards information bulletin
FTM	flight training manual
GOM	general operations manual
HAZMAT	hazardous materials
Hg	mercury
IEP	ice evidence probe

IFR	instrument flight rules
ILS	instrument landing system
IMC	instrument meteorological conditions
InFO	information for operators
KIAS	knots indicated airspeed
kts	knots
LBB	Lubbock Preston Smith International Airport
lbs	pounds
LOM	locator outer marker
LWD	left-wing-down
MAF	Midland International Airport
msl	mean sea level
NASA	National Aeronautics and Space Administration
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
NWS	National Weather Service
PF	pilot flying
PIC	pilot-in-command
PM	pilot monitoring
PMI	principal maintenance inspector
POI	principal operations inspector
QRH	quick reference handbook
RWD	right-wing-down
SAFO	safety alert for operators
SIC	second-in-command

SIGMET significant meteorological information

SLD supercooled large droplet

SN serial number

SOP standard operating procedure

STC supplemental type certificate

SVFR special visual flight rules

TAWS terrain awareness and warning system

TSB Transportation Safety Board of Canada

VFR visual flight rules

V_{ga} minimum approach airspeed for 30° flaps plus 5 kts (not corrected for wind) or 1.1 V_{mca}, whichever is greater

V_{mca} minimum control airspeed with 5° of bank and the failure of the critical engine with takeoff flaps and landing gear retracted

$V_{mHB}30$ minimum approach airspeed and target touchdown airspeed with 30° flaps

$V_{mLB}0$ minimum approach airspeed for 0° flaps

VMC visual meteorological conditions

Executive Summary

On January 27, 2009, about 0437 central standard time, an Avions de Transport Régional Aerospatiale Alenia ATR 42-320, N902FX, operating as Empire Airlines flight 8284, was on an instrument approach when it crashed short of the runway at Lubbock Preston Smith International Airport, Lubbock, Texas. The captain sustained serious injuries, and the first officer sustained minor injuries. The airplane was substantially damaged. The airplane was registered to FedEx Corporation and operated by Empire Airlines, Inc., as a 14 *Code of Federal Regulations* Part 121 supplemental cargo flight. The flight departed from Fort Worth Alliance Airport, Fort Worth, Texas, about 0313. Instrument meteorological conditions prevailed, and an instrument flight rules flight plan was filed.

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to monitor and maintain a minimum safe airspeed while executing an instrument approach in icing conditions, which resulted in an aerodynamic stall at low altitude. Contributing to the accident were 1) the flight crew's failure to follow published standard operating procedures in response to a flap anomaly, 2) the captain's decision to continue with the unstabilized approach, 3) the flight crew's poor crew resource management, and 4) fatigue due to the time of day in which the accident occurred and a cumulative sleep debt, which likely impaired the captain's performance.

The safety issues discussed in this report include the flight crew's actions in response to the flap anomaly, the continuation of the unstabilized approach, the dispatch of the flight into freezing drizzle conditions, the efficiency of the emergency response, and simulator-based training for pilots who fly in icing conditions. Nine safety recommendations are addressed to the Federal Aviation Administration.

1. Factual Information

1.1 History of Flight

On January 27, 2009, about 0437 central standard time,[1] an Avions de Transport Régional (ATR) Aerospatiale Alenia ATR 42-320 (ATR 42), N902FX, operating as Empire Airlines flight 8284, was on an instrument approach when it crashed short of the runway at Lubbock Preston Smith International Airport (LBB), Lubbock, Texas. The captain sustained serious injuries, and the first officer sustained minor injuries. The airplane was substantially damaged. The airplane was registered to FedEx Corporation (FedEx) and operated by Empire Airlines, Inc., as a 14 *Code of Federal Regulations* (CFR) Part 121 supplemental cargo flight. The flight departed from Fort Worth Alliance Airport (AFW), Fort Worth, Texas, about 0313. Instrument meteorological conditions (IMC) prevailed,[2] and an instrument flight rules (IFR) flight plan was filed.

During the flight's initial descent to LBB, the first officer was the pilot flying (PF) with the autopilot system engaged. As the airplane descended from 14,000 to 8,000 feet above mean sea level (msl), the captain, who was the pilot monitoring (PM), performed the descent and approach checklists. Review of the cockpit voice recorder (CVR) transcript revealed that the captain confirmed that the airplane's anti-icing and deicing protection was set to level 3.[3] The captain performed the approach briefing,[4] which included what he believed to be the "icing speed" information (minimum maneuvering and operating airspeeds for approach in icing conditions).[5]

According to the CVR transcript, at 0419:41, the captain briefed the first officer about the missed approach procedure for the instrument landing system (ILS) approach to runway 17R,[6] stating that "in the event of a miss it'll be uh climb to thirty seven and a right turn to five

[1] All times in this report are central standard time (unless otherwise noted) and based on a 24-hour clock.

[2] According to the Federal Aviation Administration (FAA) *Pilot/Controller Glossary*, IMC is defined as "meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling [that are] less than the [minimums] specified for visual meteorological conditions." At the time of the accident airplane's approach, LBB's ceiling and visibility were below the minimums specified in 14 CFR 91.155 for flight under visual flight rules. Information obtained from the FAA's website <http://www.faa.gov/air_traffic/publications/atpubs/PCG/> (accessed March 21, 2011).

[3] The airplane flight manual contained guidelines for using the anti-icing and deicing systems. For more information, see section 1.17.1.6.

[4] During postaccident interviews, the flight crewmembers reported that the captain performed the approach briefing because they anticipated that he would be flying the approach. They believed that weather conditions were at the minimums for the approach (ceiling 200 feet above ground level, visibility 1/2 mile), and they were unsure if the first officer had accumulated the 100 hours of flight time in the ATR 42 required by Empire Airlines for her to fly the approach to minimums. Subsequently, they learned that the weather conditions were above minimums and decided that the first officer would fly the approach.

[5] For more information about the captain's approach airspeed briefing and the flight crew's procedures for obtaining and using such information, see section 1.17.1.4.

[6] According to the CVR transcript, the air traffic controller informed the flight crew that runway 8/26 was closed and that the localizer back course approach, which the first officer recognized as the only approach for runway 35L, was unavailable. The flight crew discussed that the winds were from the north but that runway 17R was the only available option.

hundred feet[7] via the Lubbock one fourteen radial to HYDRO intersection and hold annnd[8] that looks like a parallel entry." The first officer acknowledged this statement, and the captain then stated, "climb to thirty seven and a left turn to five out to one fourteen."

At 0422:32, the LBB approach controller cleared the flight to descend to 6,000 feet msl and advised that he had not received any icing reports and that the special weather observation about 0408 indicated winds from 350° at 10 knots (kts), visibility 2 miles in light freezing drizzle and mist, ceiling overcast at 500 feet above ground level (agl), temperature -8° C, dew point -9° C, and altimeter setting 30.12 inches of mercury (Hg). At 0424:57, the captain contacted company flight operations on the radio to advise that the flight was about 15 minutes out.

At 0433:13, the controller cleared the flight for the ILS approach to runway 17R, and at 0433:52, he instructed the flight to contact the LBB tower. The captain established contact with the tower, and, at 0434:06, the tower controller cleared the flight to land and reported that the wind was from 010° at 8 kts.[9]

During postaccident interviews, both the captain and the first officer stated that the airplane accumulated ice during the descent. At 0434:24, the first officer called for a flap setting of 15°, the deployment of the landing gear, and the landing check. During a postaccident interview, the first officer recalled that the airplane subsequently accelerated in the descent, which she stated was unusual for the airplane in a flaps- and gear-down configuration. A postaccident review of information from the airplane's flight data recorder (FDR) showed that, after the first officer called for flaps, the airplane's airspeed remained about 158 kts and briefly increased to about 160 kts, and the first officer decreased engine power to about 3 percent torque. At 0435:03, about the time that the first officer reduced engine power, she stated, "what the heck is going on?" At 0435:04, the captain replied, "you know what? we have no flaps."

The FDR showed that a flap asymmetry had occurred in which the right flaps did not extend and the left flaps extended partially (8° to 10°).[10] The autopilot countered the flap asymmetry by applying aileron deflection that resulted in a 20° left control-wheel movement. The FDR indicated that, at the time the captain stated that they had "no flaps," the airplane was at an altitude of about 1,400 feet agl just outside the locator outer marker (LOM), which serves as the final approach fix (FAF).

According to the CVR transcript, after the captain commented about the flap problem, neither crewmember discussed a procedure or checklist to address it. During a postaccident interview, the first officer stated that she continued to fly the approach with the airplane coupled to the autopilot while the captain got out a flashlight and tried to troubleshoot the flap problem.

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7 The published procedure specified that the initial climb to 3,700 feet msl is followed by a climbing "left" turn to "5,000 [feet msl]" via the radial to the intersection.

8 The use of excess vowels, letters, or drawn-out syllables in any word in the CVR transcript is intended to provide a phonetic representation of the word as spoken.

9 According to the ATR 42 Airplane Flight Manual, the maximum allowable tailwind component for landing is 15 kts. The wind recorded about 0430 by the LBB automated surface observing system was from 360° at 14 kts gusting to 19 kts.

10 All references in this section to airplane configuration, airspeed, altitude agl, and engine power settings are derived from the airplane performance study. For more information about the study, see section 1.16.1.

The captain stated in a postaccident interview that he repositioned the flap handle several times and used the flashlight to check the circuit breakers behind the first officer's seat. The captain stated that, after finding that no circuit breakers were out, he moved the flap handle back to the "up" (or 0°) position because he did not want the flaps to travel inadvertently during the approach.

The FDR indicated that, between 0434:58 and 0435:25, as the airplane descended with the autopilot engaged, its airspeed decreased from about 160 to 125 kts. At 0435:30 (about 26 seconds after the captain commented about the flap anomaly), the CVR captured a sound consistent with the aural stall warning ("cricket") and the tactile stick shaker that lasted 1.1 second. The captain stated to the first officer, "yeah don't do that." At 0435:32, a 0.3-second sound consistent with the aural stall warning sounded. At 0435:36, the captain stated, "just keep flying the airplane. okay." The FDR indicated that the stick-shaker activation disconnected the autopilot when the airplane was about 900 feet agl at 125 kts indicated airspeed (KIAS).[11] The FDR also indicated that the first officer increased engine power to about 70 percent torque and began manually flying the approach. Following the application of power, the airspeed began increasing. At 0435:40, the first officer asked, "should I go around," and the captain replied, "no," and then stated, "keep descending."

At 0435:44, the first officer stated, "we're getting close here"; the CVR transcript indicated that the first officer's voice sounded as if she were straining. During a postaccident interview, the captain stated that he looked over and was surprised to see that the first officer was manually flying the approach and that he had not heard the aural alert to indicate that the autopilot had been disconnected (no alert was captured by the CVR). The captain asked the first officer if she wanted him to finish the approach; the first officer replied, "yes please."

At 0435:50, the captain took control as the PF when the airplane was about 700 feet agl at 143 KIAS. During a postaccident interview, the captain stated that the airplane was high and to the right of the approach course and that he corrected to put it back on course. According to the FDR, at 0435:56, the captain reduced the engine power to about 10 percent torque. At 0436:00, the CVR captured a 0.9-second sound consistent with the aural stall warning and the stick shaker concurrent with the terrain awareness and warning system (TAWS) warning, "pull up. pull up." According to the FDR, at this time, the airplane was about 500 feet agl at 156 KIAS. At 0436:04, the first officer stated, "there's the runway."

Between 0436:00 and 0436:17, as the airplane continued to descend, its airspeed decreased from about 156 to 129 kts. At 0436:17, the captain called for maximum propeller speed. At 0436:19, when the airplane was about 200 feet agl at 124 KIAS, the CVR captured the sounds of engine power increasing concurrent with the aural stall warning and the stick shaker. At 0436:21, the airplane was about 150 feet agl at 123 KIAS and began to roll right-wing-down (RWD).

Between 0436:21 and 0436:23, the airplane rolled right to a bank angle of 35° RWD. The airplane then rolled left to a bank angle of 50° left-wing-down (LWD) bank, and then right

[11] The published minimum airspeed for the airplane flying with the flaps retracted in icing conditions was 143 KIAS.

reaching a 10° RWD bank before it impacted the ground. At 0436:27, the CVR captured the sound of impact. During a postaccident interview, the captain reported that he had no lateral control of the airplane and that the controls were almost “snatched” out of his hands.

An airport operations agent in a vehicle on taxiway M, which parallels runway 17R/35L, was about 1,800 feet south of the approach end of runway 17R when he saw the airplane approach. He estimated that the airplane was about 400 to 500 feet agl when it emerged from the fog layer and stated that it appeared to be high and to the right of the runway centerline. He stated that the airplane appeared to be “pancaking” in its descent and that it rolled slightly to the right, then rolled hard to the left in a near-90° bank, then rolled back to the right, impacted the ground, and slid for a distance. He further stated that, as the airplane slid past his position, a fire erupted on the airplane’s right wing and “engulfed” the airplane. He stated that he immediately notified his supervisor of the accident and that he could hear the beeping tones of the crash phone over his radio as the airplane continued to slide. He stated that he soon saw the lights of the aircraft rescue and firefighting (ARFF) units emerging from their station.

The airplane came to rest next to the right side of the runway (about 200 feet west of the runway centerline), north of taxiway S. Figure 1 is an aerial view of the approach end of runway 17R and the location of the wreckage. The ARFF units, which were on the accident scene within about 4 minutes, were the first responders to arrive. The ARFF response was joined by Lubbock Fire Department units, one of which could not enter at the designated airport access gate because the gate would not open; the unit was diverted to a different gate to enter the airport.[12]

[12] For more information about the emergency response, see section 1.15.2.

Figure 1. Aerial view of approach end of runway 17R and location of wreckage.

1.2 Injuries to Persons

Table. Injury Chart

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	0	0	0	0	0
Serious	1	0	0	0	1
Minor	1	0	0	0	1
None	0	0	0	0	0
Total	2	0	0	0	2

1.3 Damage to Airplane

The airplane was substantially damaged by the impact forces and postcrash fire.

1.4 Other Damage

The airport approach lighting system and the runway were damaged during the accident sequence.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 52, held an airline transport pilot certificate with ratings for single-engine and multiengine land airplanes. His most recent Federal Aviation Administration (FAA) first-class medical certificate was issued on September 19, 2008, with a limitation that he must "possess glasses for near/intermediate vision." According to Empire Airlines' records, the captain had accumulated 13,935 total flight hours, including 12,742 hours as pilot-in-command (PIC). He had a total time in the ATR 42 of 2,052 hours, 1,896 hours of which were as PIC. In the 90 days, 30 days, and 24 hours before the accident, the captain accumulated about 53, 13, and 5 hours, respectively.

The captain was hired by Empire Airlines on May 9, 1988. Employee training records showed that the captain had previously flown and served as a check airman on the company's Cessna 208 (single-engine, turbopropeller-powered) airplanes, in which he had accumulated about 6,600 total flight hours. He had also previously flown the company's Fokker F27 (multiengine, turbopropeller-powered) airplanes, in which he had accumulated about 2,500 total flight hours, about 1,900 hours of which were as PIC. Employee training records showed that the captain completed his most recent recurrent proficiency check ride and line check on September 22, 2008. His most recent recurrent ground training, which focused on ATR 42 systems, was completed on March 29, 2008. A review of FAA and company records revealed that the captain had no previous FAA enforcement actions, incidents, or accidents.

The captain was experienced with in-flight icing conditions because he had worked as a pilot in the Pacific Northwest and Alaska for 30 years. He stated that he had been dispatched into freezing drizzle before and that, while flying in such conditions, he maintained a heightened awareness of the flying environment.

The first officer described the captain as someone whom she would feel comfortable speaking up to, if necessary. She stated that the captain sought her input and asked for her opinion and that, at the beginning of their trip pairing, the captain told her that she should tell him if she saw him do anything wrong. Other Empire Airlines' pilots who had flown with the captain stated that his greatest strength as a pilot was his experience level. One pilot stated that the captain occasionally cut corners, seemed rushed, was less thorough on briefings than other captains, and became easily agitated when flying and driving.

1.5.2 The First Officer

The first officer, age 26, held a commercial pilot certificate with ratings for single-engine and multiengine land and instrument airplanes. Her most recent FAA first-class medical certificate was issued on December 4, 2008, with no limitations. According to Empire Airlines' records, the first officer had accumulated 2,109 total flight hours, about 1,890 hours of which were as PIC. She had accumulated 130 hours in the ATR 42 as second-in-command (SIC). In the 90 days, 30 days, and 24 hours before the accident, the first officer accumulated about 88, 29, and 5 hours, respectively.

The first officer was hired by Empire Airlines on July 25, 2008. Employee training records showed that the first officer completed her most recent proficiency check ride (an initial check) on September 10, 2008. Her most recent ground training, which was initial training for the ATR 42, was completed on August 29, 2008. A review of FAA and company records revealed that the first officer had no previous FAA enforcement actions, incidents, or accidents.

The first officer had limited experience flying in icing conditions before working for Empire Airlines, and the ATR 42 was the first airplane in which she had flown that was equipped with deicing and anti-icing systems.

Other Empire Airlines pilots who had flown with the first officer described her flying skills as "at par" or "average" compared to other first officers with the same experience level. One pilot stated that the first officer was methodical about using checklists. Another pilot stated that the first officer's greatest strength as a pilot was that she was "nonconfrontational." One captain described the first officer's crew resource management (CRM) skills as "good," and another captain stated that the first officer did not seem to have a problem speaking up, if needed. Regarding areas in which the first officer could improve, one pilot stated that "she could employ the skills she already knew without asking so many questions," and another pilot stated, "more hands-on flying of the airplane."

1.5.3 Flight Crew's Rest Opportunities

1.5.3.1 The Captain

The captain reported that, on January 24, 2009, he awoke about 0800. From about 1015 to 1535, he traveled as a passenger on commercial flights to reposition from his home in Portland, Oregon, to Midland International Airport (MAF), Midland, Texas. The captain went to bed about 2200 in his hotel room in Midland, Texas. On January 25, 2009, the captain awoke about 0800, performed various activities throughout the day (including exercising, reading, shopping, and going to dinner at a coworker's home with the first officer), and went to bed about 2200.

The captain stated that, on January 26, 2009, he awoke about 0400 to prepare for the upcoming night flight. He performed various activities and then slept from about 1100 to 1630. He stated that he met the first officer in the hotel lobby about 1820 and that they drove to MAF to begin duty about 1845. They departed MAF about 1945, arriving at El Paso International Airport (ELP), El Paso, Texas, about 2115. They subsequently departed ELP for AFW about 2230, arriving about 0030 on January 27, 2009. The flight crew then departed AFW for LBB (the accident flight) about 0313.

During postaccident interviews, the captain indicated that he needed 6 to 8 hours of sleep per night to feel rested. He stated that he considered himself to be a night person and that he felt rested before the accident flight. He described his workload on the day of the accident as normal overall but stated that, during the approach, the workload was high. The captain stated that takeoffs and landings were high-workload situations and that the icing conditions and flap anomaly elevated his workload.

1.5.3.2 The First Officer

The first officer (who was based in Salt Lake City, Utah)[13] had first arrived in Midland, Texas, on January 18, 2009, to fly a trip sequence with another captain and had completed that trip sequence on January 23, 2009. During those trips, the first officer was on duty during night hours beginning about 0045. After the first officer completed that trip sequence, Empire Airlines paid the expenses for the first officer to spend the weekend in Midland, Texas, rather than have her commute home on a short turnaround. The first officer indicated that she was off duty from the afternoon of January 24, 2009, until the evening of the accident flight. The first officer indicated that, because her previous trip sequence and the accident trip sequence required her to sleep during the day and be awake at night, she maintained that same sleep schedule during her off-duty time (between the two trip sequences) in Midland, Texas.

On January 24, 2009, the first officer went to bed about 0600 in her hotel room and awoke about 1430. She then performed various activities throughout the day and evening (including exercising and going to the store) and went to bed about 0600 on January 25, 2009. She awoke about 1400, later met the captain to go to dinner at a coworker’s home, returned to the hotel about 2200, and went to bed sometime in the morning on January 26, 2009. The first officer awoke about 1500 and reported for her trip duty with the captain about 1845.

During postaccident interviews, the first officer indicated that she needed 7 hours of sleep to feel rested. She stated that she considered herself to be a night person and that she felt rested before the accident flight. She described her workload on the day of the accident as normal but stated that the workload became high when she and the captain realized that the flaps did not function properly. The first officer stated that although the workload during the approach was high, she felt that it was something that they could handle.

1.6 Airplane Information

1.6.1 General

The accident airplane (model ATR 42-320, serial number [SN] 175) received its airworthiness certificate in 1990. In 2005, the airplane was configured for freight operations in accordance with supplemental type certificate (STC) ST01189W1.[14] The airplane was powered by two Pratt & Whitney Canada PW 121 engines, each equipped with a Hamilton Standard 14SF propeller. According to the type certificate data sheet, the ATR 42 is certificated for flight in known icing conditions in accordance with 14 CFR Part 25, Appendix C, which details the types of icing exposures for which the aircraft is tested and certificated. The airplane’s most recent inspection (a 2-month inspection) was completed on January 9, 2009. At the time of the accident, the airplane had accumulated 28,768 hours of operating time and 32,379 cycles.

[13] Salt Lake City, Utah, was a “floater” base for Empire Airlines. Flight crews based there would commute to various cities based on the company’s needs and at the company’s expense.

[14] STC ST01189W1 is held by M7 Aerospace LP.

The airplane had no deferred maintenance items, and the maintenance records showed compliance with all applicable airworthiness directives (ADs) for the airframe, propeller subassemblies, and the right engine.[15] The AD tracking form for the left engine was not located. During the investigation, an Empire Airlines records clerk located work orders and records of other required directives to demonstrate AD compliance for the left engine.

The airplane's maximum gross takeoff and landing weights were 37,258 and 36,155 pounds (lbs), respectively. A review of the FedEx Feeder Aircraft Load Control Sheet and the Empire Airlines Cargo Load Manifest for the flight revealed that the accident flight's calculated takeoff and estimated landing weights were 34,487 and 32,717 lbs, respectively, and that its calculated center of gravity (CG) was within limits.

1.6.2 Flap System

The ATR 42 is equipped with four trailing-edge flaps (two per wing) that are electrically controlled and hydraulically operated (each flap has a hydraulic actuator). The flight crew can command the flaps into four positions using the cockpit flap control lever: 0° for cruise flight, 15° for takeoff and approach, 30° for landing, and 45° for use during an emergency.[16] During normal operations, all flaps move together when commanded.

An interconnection torque shaft is connected to the left and right inboard flaps. Both a flap position transmitter, which provides flap position information to the flap indicator in the cockpit, and a flap asymmetry detector are attached to the interconnection torque shaft. The flap position transmitter is mounted near the center of the interconnection torque shaft and senses the average position of the flaps based on movement of the torque shaft. The flap asymmetry detector is designed to prevent any asymmetry between the right and left flaps from exceeding 8° to 10° (the precise value depends upon the flap positions when the asymmetry occurs). If a flap asymmetry reaches the determined value, a microswitch integrated into the detector cuts off the electrical power supply to the flap control switch, and the flap extension or retraction solenoid is no longer energized. As a result, the flaps will stop in the positions reached at the time of the power interruption. Once this occurs, the flaps will not move in response to movement of the flap control lever in the cockpit until maintenance personnel reset the system on the ground.[17]

If a flap asymmetry occurs due to a restriction (jam) and the restriction is then removed, hydraulic pressure in the system will move the flaps to a symmetrical position. The resulting flap position will be the average of the right and left flap positions when the asymmetry occurred. Even if such hydraulic balancing of the flaps occurs, post-flight maintenance action would still be required to restore electrical power to the flap control switch.

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[15] The airframe AD compliance records were located throughout the airplane's records, the propeller subassembly ADs were tracked through Empire Airlines' computerized maintenance tracking system, and the right engine ADs were listed on an AD tracking form located with the right engine logbooks.

[16] The four flap positions are standard increments. In the ATR 42, for some selected settings, the actual position of the flaps differs by a few degrees from the indicator increment (the 30° flap position increment represents 27° of actual flap deflection).

[17] For more information about the flight crew's procedures for responding to a flap asymmetry, see section 1.17.1.1.

A flap position indicator in the cockpit has an index marked with the four flap positions (shown as 0°, 15°, 30°, and 45°), and a needle pointer indicates the flap position on the index. If a flap asymmetry occurs, the flap indicator needle in the cockpit will point to the index value that corresponds with the average position of the flaps. Figure 2 shows the flap position indicator, and the inset depicts the likely needle pointer position during the flap asymmetry.

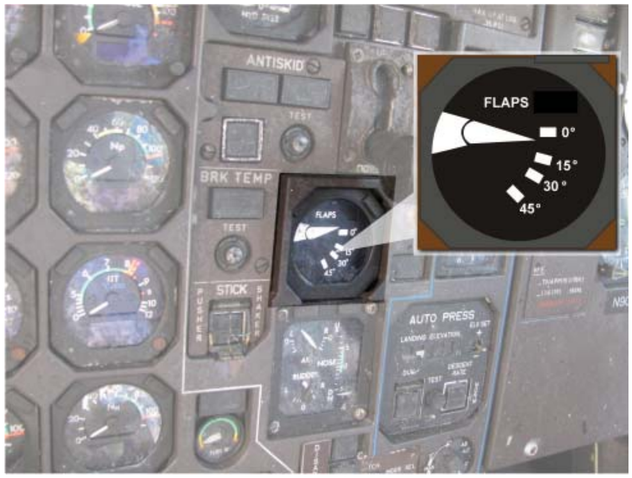

Figure 2. Flap position indicator. Inset shows the likely needle pointer position during the flap asymmetry.

In addition to the cockpit flap position indicator, exterior flap position fairings mounted on the wings (one per wing) are visible to each flight crewmember through their respective side windows. These fairings are also marked with lines and numbers for the four flap positions, providing flight crews with a visual indication of the actual position of each flap. Figure 3 shows the exterior flap position fairing. The wing flap position fairings are illuminated by the wing lights during nighttime use. If a flap asymmetry occurs, the actual positions of the right and left flaps will be indicated on the respective flap position fairings.

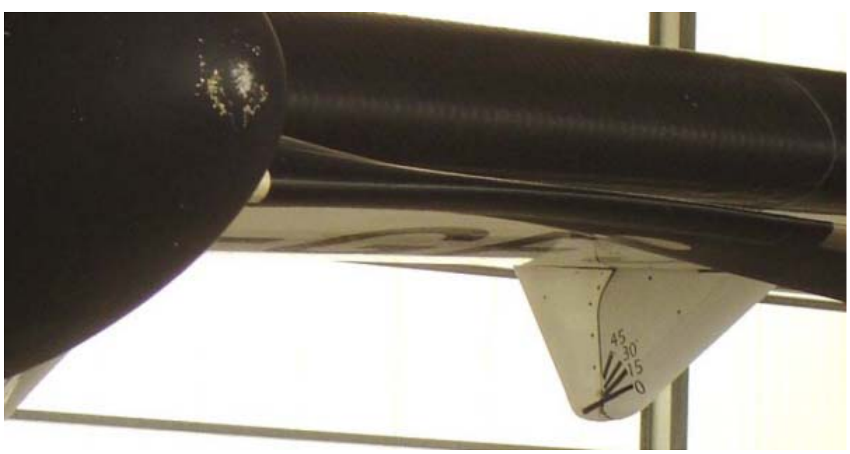

Figure 3. Exterior flap position fairing.

1.6.3 Deicing, Anti-Icing, and Anti-Icing Advisory Systems

The ATR 42's ice protection system permits the airplane to operate in some atmospheric icing conditions (applicable restrictions are noted in the limitations section of the airplane flight manual [AFM]).[18] The leading edges of the ATR 42's wings, horizontal stabilizers, and vertical stabilizer are equipped with pneumatic deice boots that are inflated by engine compressor bleed air.[19] When the flight crew selects airframe pneumatic boot use, pockets in the boot system inflate in sequence, perpendicular to the airfoil, to deice the leading edges.

The propeller blades, windshields, probes (pitot, static, air temperature, and angle-of-attack [AOA]), and flight control horns[20] are electrically heated. The horn anti-icing feature prevents ice deposits from forming between the wing structure and the moving parts of the control surfaces. A pneumatic system provides deicing protection for the engine intakes and is designed to prevent a reduction or total loss of engine performance in icing conditions.

According to the ATR 42 flight crew operating manual (FCOM), the ATR 42 has an anti-icing advisory system (AAS) designed to alert the flight crew to apply the correct procedures when flying in icing conditions.[21] The AAS includes an ice detector (mounted under the left wing) and three cockpit light annunciators; the amber ICING light and green ICING AOA light are on the central panel, and the blue DEICING light is on the memo panel. The AAS alerts the flight crew as soon as (and as long as) the ice detector detects ice accretion. Once the probe detects at least 0.5 millimeter of ice, the amber ICING light illuminates. The AAS self-tests continuously, and any failure illuminates a FAULT light with a single chime.

1.6.4 Flight Instruments

1.6.4.1 Airspeed Indicator

The ATR 42 is equipped with three analog airspeed indicators (one on each pilot's instrument panel and one on the central panel). Each airspeed indicator has a moving needle pointer that indicates the airplane's KIAS on a fixed scale that shows 60 to 400 kts. Each airspeed indicator has four moveable indices, known as "bugs" (one internal and three external), on the outer scale that the pilot uses to manually set certain airspeed references for takeoff or landing, based on airplane performance information for the flight conditions.[22]

The internal bug, which is underneath the glass face of the airspeed indicator, is set by the pilot using a selector knob. According to the ATR 42 pilot handbook, for approach and landing in icing conditions, the internal bug should be set to V_{mHB}30 icing, which is the minimum

[18] For more information about these restrictions, see section 1.17.1.6.

[19] The vertical stabilizer deice boots are optional on ATR 42s.

[20] The airplane's primary flight controls (ailerons, elevators, and rudder) are mechanically operated and have counterweights, or horns, that serve to balance the controls.

[21] For information about flight crew procedures for responding to each AAS annunciator, see section 1.17.1.6.

[22] For information about obtaining applicable airspeed references and setting the bugs, see section 1.17.1.4.

approach airspeed and target touchdown airspeed with 30° flaps in icing conditions.[23] The airspeed indicated by the internal bug (as selected by the pilot using the selector knob) controls the reference on the electronic attitude direction indicator (EADI) fast/slow scale.[24]

The other three indices, which are located on the outside of the glass face of the airspeed indicator, are color coded for use in referencing certain airspeeds during takeoff or landing and are manually positioned by the pilot. Unlike the internal bug's function, the pilot's positioning of these three indices (yellow, white, and red) does not affect any other systems or displays. The ATR 42 pilot handbook states that, for an approach, the yellow bug should be set to reference V_{ga}, which is the approach airspeed for 30° flaps plus 5 kts (not corrected for wind effect).[25] Similarly, the white bug should be set to reference $V_{mLB}0$ normal, which is the minimum airspeed for an approach with 0° flaps in nonicing conditions, and the red bug should be set to reference $V_{mLB}0$ icing, which is the minimum airspeed for an approach with 0° flaps in icing conditions. Figure 4 is an airspeed indicator showing the needle pointer; selector knob; and internal, yellow, white, and red bugs.

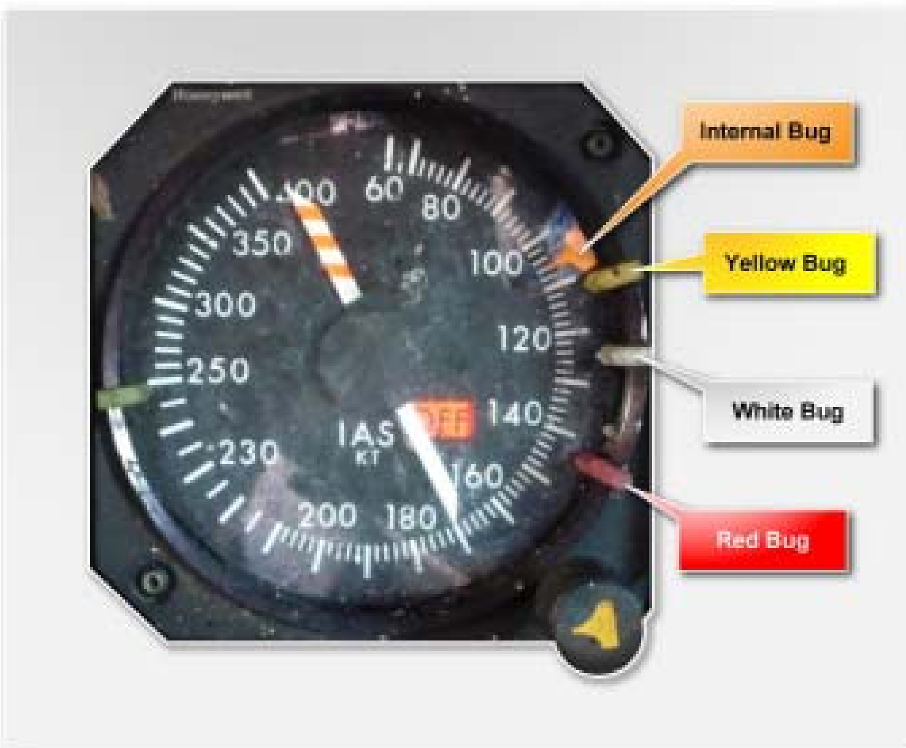

Figure 4. Airspeed indicator showing needle pointer; selector knob; and internal, yellow, white, and red bugs.

[23] The ATR 42 pilot handbook notes that this speed is to be corrected for wind and that the wind factor is 1/3 of the headwind velocity or the gust in full, with a maximum wind factor of 15 kts.

[24] For more information, see section 1.6.4.2.

[25] The ATR 42 pilot handbook states that for V_{ga}, pilots should use the higher of $V_{mHB}30$ + 5 kts (not corrected for wind) or 1.1 V_{mca} (1.1 times the minimum control airspeed with 5° of bank and the failure of the critical engine with takeoff flap and landing gear retracted).

1.6.4.2 Electronic Flight Information System

The airplane's electronic flight information system includes displays for each pilot on the cockpit instrument panel. Each pilot's display includes an EADI to indicate the airplane's pitch and roll relative to the horizon. The EADI depicts the horizon as a straight, horizontal line between the blue upper half of the display (showing the relative location of the sky), and the brown lower half (showing the relative location of the ground). The pitch scale is marked in 5° intervals, and the roll scale indicates select bank angles between 0° and 60°.

The left side of each EADI also displays a "fast/slow" scale that indicates the difference between the airplane's actual airspeed and the target airspeed as selected by the pilot using the internal bug on the airspeed indicator. An index on the fast/slow scale moves up (fast) or down (slow) according to any deviation of the actual airspeed from the selected airspeed.

1.6.5 Automatic Flight Control System

The airplane was equipped with an automatic flight control system that provided autopilot, yaw damper, flight director, and altitude alert functions. The autopilot system is designed to automatically disconnect when certain system conditions occur, including achieving the stall warning threshold. If an autopilot disconnect occurs (either automatically or manually), indications provided to the flight crew include an aural alert ("cavalry charge" tone),[26] a message ("AP DISENGAGED") on the advisory display unit (ADU), and a visual annunciator ("AP MSG") on the primary flight display. With the autopilot system engaged, if an anomaly in the airplane's roll characteristics occurs (such as those that a flap asymmetry would induce), the ADU will show "RETRIM ROLL R [or L] WING DN" and "AILERON MISTRIM" messages.

1.6.6 Stall Protection System

The airplane's stall protection system includes two AOA probes (one on each side of the forward fuselage) that detect the airplane's AOA, an aural stall warning ("cricket"), a tactile stick shaker, and a stick pusher. According to ATR, when the airplane is configured for flight in nonicing conditions with flaps 0°, if the AOA probes detect that the airplane has reached a critical AOA of 11.6°, the aural stall warning sounds, and the stick shaker activates. If the probes detect that the AOA continues to increase, the stick pusher activates between 11.5° and 13.8°, depending on the AOA's rate of change.

The stall protection system is designed to provide an earlier stall warning threshold during flight in icing conditions. According to ATR, when the airplane is configured with the control horns' anti-icing selected on with flaps 0°, the critical AOA for activation of the aural stall warning and the stick shaker is reduced to 7°, and the stick-pusher activation remains at an angle between 11.5° and 13.8°.

[26] The aural warning can be inhibited by other aural warnings with higher priority.

1.7 Meteorological Information

Freezing precipitation in the form of light freezing rain and ice pellets began at LBB about 2300 on January 26, 2009. The precipitation later changed to light freezing drizzle, which continued until after the accident.[27]

The LBB weather observation about 0353 reported wind from 010° at 14 knots, visibility 3 miles in light freezing drizzle and mist, ceiling overcast at 500 feet agl, temperature -8° C, dew point -9° C, and an altimeter setting 30.13 inches of Hg. The LBB weather observation about 0453 reported wind from 020° true at 13 kts gusting to 18 kts, visibility 2 miles in light freezing drizzle and mist, ceiling overcast at 500 feet agl, temperature -8° C, dew point -9° C, and an altimeter setting 30.13 inches of Hg. The remarks section of the weather observation indicated that the ceiling was variable from 400 to 900 feet agl and that the hourly liquid equivalent precipitation was less than 0.01 inch (a trace of precipitation).

The National Weather Service (NWS) terminal aerodrome forecast for LBB expected IFR conditions to prevail during the period including the accident flight's arrival with wind from 030° at 12 knots, visibility of 1 1/2 miles in light freezing drizzle and mist, and ceiling overcast at 100 feet agl through about 0800, with a temporary period of visibility 1/2 mile in light freezing drizzle and freezing fog. The NWS also had issued an airmen's meteorological information (AIRMET) for moderate icing conditions[28] from the freezing level through 22,000 feet msl over Texas that was current at the time of the accident. A review of the NWS current icing potential and supercooled large droplet (SLD) icing diagnostic charts indicated a greater-than-80-percent probability of icing conditions over the LBB area from the surface through 6,000 feet msl and a high likelihood of encountering SLD conditions. Temperatures were above freezing between 6,000 and 11,000 feet msl as a result of a temperature inversion.

1.8 Aids to Navigation

No problems with any navigational aids were reported.

[27] As defined by the American Meteorological Society Glossary and the National Weather Service *Federal Meteorological Handbook*, freezing drizzle is drizzle that falls in liquid form but freezes upon impact with surfaces to form a coating of glaze; freezing drizzle has a diameter between 0.05 to 0.5 millimeters (0.002 to 0.02 inches) at temperatures less than 0° C.

[28] According to the FAA's *Aeronautical Information Manual* (AIM), when reporting icing to air traffic control, pilots should describe the icing intensity as moderate when the rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary. Information obtained from the FAA's website <http://www.faa.gov/air_traffic/publications/ATpubs/AIM/> (accessed March 21, 2011). FAA Advisory Circular 91-74A, "Pilot Guide: Flight In Icing Conditions" published in December 2007, states that, in icing of moderate intensity, "the rate of ice accumulation requires frequent cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour on the outer wing. The pilot should consider exiting the condition as soon as possible."

1.9 Communications

No problems with any communications equipment during the flight were reported. During a postaccident interview, the first officer stated that, after the accident, the captain attempted to contact the air traffic control tower (ATCT) using the airplane's radios but that the radios were inoperative. The CVR transcript indicates that the CVR captured the sound of impact at 0436:27, a subsequent sound similar to occupants moving around in the cockpit, the captain's instructions about exiting the airplane, and the sound of the door opening at 0437:25. No further sounds were captured, and the recording ended at 0441:35.

1.10 Airport Information

LBB is located about 4 miles north of the city of Lubbock, Texas, at an elevation of 3,282 feet msl. LBB is a Class I public airport certificated under 14 CFR Part 139.[29] Runway 17R/35L, which is the longest of the airport's three runways,[30] has a concrete surface and is 11,500 feet long and 150 feet wide.

LBB maintained ARFF capabilities at Index C[31] and had four vehicles, three of which (Rescue 1, 2, and 4) were equipped with a roof turret, bumper turret, and hand line; each vehicle carried 1,500 gallons of water, at least 190 gallons of aqueous film forming foam (AFFF), and 450 lbs of dry chemical. The remaining vehicle (Rescue 5), which was equipped with a hand line, carried 450 lbs of dry chemical and 100 gallons of a mixture of water and AFFF. The ARFF station was centrally located south of taxiway J near the midpoint of runway 8/26. ARFF services were available 24 hours a day, every day, and the station was staffed by a minimum of four firefighters. Five firefighters, all of whom participated in the response, were on duty at the time of the accident.[32]

1.10.1 Emergency Plan

LBB had an FAA-approved airport emergency plan (AEP) that provided guidance intended to minimize the possibility and extent of personal injury and property damage during an emergency. The FAA approved the most recent revisions to the AEP on July 9, 2008. The AEP stated that, during an emergency response, "primary entry points to the airfield by responding units will be at Gate 6 and Gate 48 or at a location prescribed by the command post." The AEP stated that "the Battalion Chief will set up the initial staging area/command post near Gate 6, Gate 48, or another designated area."

[29] Title 14 CFR 139.5 states that a Class I airport is certificated to serve scheduled operations of large air carrier aircraft and can also serve unscheduled passenger operations of large air carrier aircraft and/or scheduled operations of small air carrier aircraft.

[30] Runway 8/26, which has a concrete surface, is 8,001 feet long and 150 feet wide, and runway 17L/35R, which has an asphalt surface, is 2,891 feet long and 75 feet wide.

[31] LBB was an Index C airport based on five or more average daily departures of aircraft with a length of at least 126 feet but less than 159 feet, as defined in 14 CFR 139.315. For an airport to meet Index C capabilities, 14 CFR 139.317 requires two or three ARFF vehicles that contain at least the minimum specified amount of various extinguishing agents.

[32] For more information about the emergency response, see section 1.15.2.

If an accident occurs, the ATCT notifies the ARFF station through the direct line radio to the station. According to the letter of agreement between the LBB ATCT and the City of Lubbock, upon the alert activation, the ATCT controller should provide, "as is available," the "type of aircraft, nature of the emergency, runway to be used, and any other information if time permits."

1.10.2 Snow and Ice Control Plan

As required by 14 CFR 139.313, LBB maintained an FAA-approved snow and ice control plan. According to the airport's snow and ice operations document, the operations supervisor, operations agent on duty, or maintenance supervisor is responsible for monitoring the runway and taxiway environment to determine when snow and ice removal is needed. Sensors embedded at various points on the runways, taxiways, and the terminal ramp detect surface and subpavement temperatures and surface moisture, and information from the sensors is monitored from the airfield maintenance building by airport maintenance personnel.

The snow and ice operations document indicated that, during critical temperatures, if moisture or precipitation is occurring or is expected to occur, granulated urea will be applied to the first priority airport operational surfaces, such as the active runway, its parallel taxiway, taxiways connecting the active runway to the terminal ramp, and the established ARFF road from the fire station to taxiway J. The assistant airport manager stated that the road from the fire station to taxiway J had received a urea application before the accident flight's arrival. No written record exists to indicate when this application occurred.

The snow and ice operations plan did not address monitoring or ensuring the operability of the airport emergency response and mutual aid gates. FAA Advisory Circular (AC) 150/5200-30C, "Airport Winter Safety and Operations," which provides guidance to assist airport operators in developing a snow and ice control plan, also did not address this topic. An informal survey of other 14 CFR Part 139 airports where operations are affected by winter weather revealed that none of the airports' snow and ice control plans addressed gate operability.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The accident airplane was equipped with a Fairchild Model A100A CVR, SN 59653, capable of recording four channels of analog audio on a continuous loop tape. An examination of the CVR at the National Transportation Safety Board's (NTSB) vehicle recorders laboratory found no evidence of structural or heat damage, and audio information was extracted without difficulty.

The extracted 30-minute, 43-second recording consisted of three channels of useable audio information that captured events from before the flight's descent to several minutes after the accident. Excellent quality audio[33] was obtained from the channels for the captain's and the

[33] In an excellent quality recording, virtually all of the crew conversations can be accurately and easily understood, and only one or two words are not intelligible; any loss is usually attributed to simultaneous cockpit

first officer's audio panels, and good quality audio was obtained from the channel for the cockpit area microphone. The fourth channel (the use of which was not required by Federal regulations) contained no audio information.

1.11.2 Flight Data Recorder

The accident airplane was equipped with a Fairchild Model FA2100 FDR, SN 289112. The FDR was sent to the NTSB's laboratory for readout and evaluation; it was received in good condition, and the data were extracted normally from the recorder. The FDR recorded about 56 hours of data, and the accident flight is reflected in the final 2 hours 18 minutes of the recording. The FDR system was configured to record more than 70 parameters of airplane flight information in a digital format using solid-state flash memory as the recording medium. For this investigation, 58 parameters that were considered relevant were verified and examined. The relevant parameters included flap position, flap asymmetry, left and right aileron surface positions, KIAS, glideslope and localizer deviations, radio altitude (altitude as sensed by the radio altimeter), AOA, roll, pitch, pitch trim, right control column position, control wheel position, airframe deicing, left and right elevator positions, and left and right engine propeller speed.[34]

1.12 Wreckage and Impact Information

Examination of the accident site showed that the airplane initially impacted flat, grassy terrain about 300 feet north of the runway 17R blast pad.[35] Ground scars and debris from the airplane extended about 2,500 feet south from that location to where the main wreckage came to rest next to the right side of the runway (about 200 feet west of the runway centerline), north of taxiway S. Fragments of the nose landing gear, right main landing gear, and a separated outboard section of the right aileron were identified in the initial debris field near the beginning of the runway.

Examination of the wreckage found that the airplane was resting on its nose section and leaning to the right; the left main landing gear remained attached. Sections of the upper fuselage, right wing, and right inboard and outboard flaps were destroyed by fire. The left engine remained secured to the wing, and the left propeller sustained minimal damage. The right engine and the right propeller sustained impact and fire damage.

conversations and/or radio transmissions that obscure each other. In a good quality recording, most of the crew conversations can be accurately and easily understood, but several words or phrases are not intelligible; any loss can be attributed to minor technical deficiencies, momentary dropouts in the recording system, or a large number of simultaneous cockpit conversations and/or radio transmissions that obscure each other.

[34] For information regarding the relevant parameters that were used in performing the airplane performance study, see section 1.16.1.

[35] A blast pad, which is unusable for landing, takeoff, or taxiing, is designed to eliminate the erosive effect of the high wind forces produced by airplanes at the beginning of their takeoff roll. The blast pad for runway 17R is a concrete extension north of the threshold that can also serve as a stopway in the event of a rejected takeoff on runway 35L.

1.13 Medical and Pathological Information

On the morning of January 27, 2009, the captain and the first officer participated in breath analysis testing for alcohol and provided urine specimens for company drug testing.[36] The tests yielded no evidence of alcohol or drug use by either crewmember.

1.14 Fire

A fuel-fed fire erupted during the accident sequence and destroyed sections of the airplane and some cargo before being suppressed by firefighting personnel. According to the airplane's dangerous goods manifest, 25 lbs of dry ice, one package of seatbelt pretensioners, and two containers of materials classified as "ORM-D [other regulated materials-domestic] consumer commodity" were destroyed in the fire. Other hazardous material (HAZMAT) on board, which included five containers of liquid chloride, one container of liquid sodium chlorite, and one container of solid sodium iodine (all radioactive materials), were undamaged.

1.15 Survival Aspects

1.15.1 Flight Crew Egress

According to the CVR transcript, after the airplane came to a stop, the captain told the first officer to "go out the hatch" but then stated, "there's a fire on the right hand side. go out the left." During a postaccident interview, the first officer stated that she first opened the cockpit escape hatch and saw a "raging fire" on the airplane's right side. She stated that she then went to the forward cargo door, unlocked it, and pushed it open with the help of the captain. The first officer stated that they "jumped out and ran to FedEx." The captain stated that, once they were outside the airplane and a safe distance from it, he called Empire Airlines' dispatch to report the accident. Both the captain and the first officer left the accident scene before the first responders arrived.

1.15.2 Emergency Response

The ATCT notified the ARFF station of the accident through the direct line radio. According to LBB ARFF personnel, a tone sounded in the fire station, followed by "muffled voices." Shortly thereafter, a second tone sounded, and an Alert 3 (which indicates an accident on or near the airport) was announced. According to the dispatch logs from the Lubbock Fire Department, the alarm sounded at 0438:12, and three ARFF units (Rescue 2, 4, and 5) were dispatched at 0438:46 and arrived on scene at 0442:31.

The ARFF captain, who was driving Rescue 5, reported that the three ARFF units proceeded along taxiway J toward taxiway M. He stated that ice was on the runways and taxiway and that he proceeded with caution because of the potential for slippery conditions. The ARFF equipment operator driving Rescue 2, which also carried an ARFF lieutenant and another

[36] Empire Airlines' drug testing program checked the samples provided for evidence of marijuana, cocaine, amphetamines, opiates, and phencyclidine use.

firefighter, estimated that they proceeded no faster than 45 mph. While en route to the accident site, the ARFF equipment operator driving Rescue 2 contacted the ATCT controller to ask what type of airplane had crashed and how many passengers were on board; the ATCT controller replied that it was an ATR carrying an unknown number of people.

The ARFF lieutenant in Rescue 2 stated that the darkness and fog made it difficult at times to distinguish between smoke and fog. The ARFF captain driving Rescue 5 stated that, after turning onto taxiway M, he saw both smoke and the glow from the fire. The ARFF captain stated that heavy smoke and flames engulfed the airplane from the cockpit to the wing section and extended just aft of the wing, where most of the flames were present. The ARFF equipment operator driving Rescue 2 stated that they immediately began applying foam and water to the wreckage and, within about 45 seconds, suppressed the fire to the extent that they could see the FedEx logo on the airplane's tail. He indicated that, because of the logo, he knew that it was a cargo airplane and that he would expect two to three occupants. He stated that he then heard Rescue 5's call to start looking for survivors.

The ARFF captain stated that the fire was "blackened down" quickly. The ARFF lieutenant from Rescue 2 accessed the cabin area from a burn hole in the fuselage to look for occupants, and another firefighter from Rescue 2 used a ladder to access the cockpit roof hatch to look inside. After observing that no one was inside the airplane, ARFF personnel from Rescue 2 and Rescue 5 immediately began searching the area for the airplane's occupants by performing visual and thermal imaging searches.

According to standard protocol for an Alert 3 accident, Lubbock Fire Department units also responded and were dispatched at 0441:10. The response included the battalion chief and engine from Station 2 (which is about 3.2 miles from LBB and staffed with personnel who are all ARFF-certified firefighters with airport access badges); an engine from Station 5 (about 7 miles from LBB); and an engine, truck, and HAZMAT team from Station 4 (about 7 miles from LBB).

As directed, one engine from Station 2 responded to Gate 48, which is an electronically controlled gate operated by a drive chain. The engine team was unable to enter the airport property at Gate 48 because the gate had ice in its operating mechanism and would not open. The Station 2 engine then drove to the ARFF station to proceed from that point. All other responding Lubbock Fire Department units were informed that the wreckage was closest to the FedEx hangar and were rerouted to respond to that site. A FedEx employee who opened the gate near the FedEx hangar for the Station 2 team, Station 5 engine, and emergency medical service (EMS) personnel informed them that the pilots were at the hangar; the EMS units proceeded to the hangar. Figure 5 is a view of the airport showing the relative locations of airport access gates and the accident site.

Figure 5. View of airport showing relative locations of airport access gates and accident site.

The first Lubbock Fire Department unit arrived on scene at 0457:27. At that time, the ARFF units had contained the fire, with the exception of a few deep-seated cargo fires inside the airplane. The Lubbock Station 2 battalion chief assumed incident command and informed the ARFF captain that the flight crew was at the FedEx hangar. The ARFF captain stopped the search for survivors, and ARFF personnel resumed their fire suppression activities. The Station 2 battalion chief and ARFF personnel indicated that the ATCT controller later called and stated that a pilot was walking around on the ramp looking for assistance, and a second search for survivors was initiated. ARFF personnel determined that both pilots were being transported to a local hospital, and the emphasis on fire suppression resumed.

The Lubbock battalion captain (who assumed command of operations from the Lubbock Station 2 battalion chief) stated that, about 5 to 10 minutes after he arrived on scene, the Lubbock Police Department delivered a HAZMAT manifest that FedEx employees had provided. The fire department had not requested the information. The Lubbock Station 2 battalion chief stated that the HAZMAT team responded to the FedEx hangar to obtain the material safety data sheets for the materials on the HAZMAT manifest. The ARFF captain stated that he did not see the HAZMAT manifest on the airplane but that he was aware that such a document existed and was available. The ARFF captain stated that the ARFF response to the accident scene would have been similar if they had known that HAZMAT was on board the airplane, with the exception that all responding firefighters would have worn full personal protective equipment.

1.16 Tests and Research

1.16.1 Airplane Performance Study and Simulator Evaluations

The NTSB conducted an airplane performance study to estimate the airplane's position, airspeed, altitude, and other parameters throughout the accident flight. Data sources for the study included the airplane's FDR, FAA air traffic control (ATC) radar data, and weather information services.[37] The study extracted aerodynamic coefficients from the FDR data. In addition, ATR used its ATR 42-320 engineering model to which accident flight-specific information was applied (including FDR data and weather information) to estimate control forces, AOA, and ice accretion levels during the accident flight. Further, the NTSB used an ATR 42-320 engineering flight simulator (EFS) provided by ATR to conduct qualitative testing to assess pilot workload and to evaluate the airplane's handling qualities with a flap asymmetry and ice accretion. The EFS could not reproduce the accident airplane's drag levels from ice accretion without introducing unrealistic lift and pitch, roll, and yaw moments;[38] as a result, the "Normal Icing—Boots On" ice levels were used with the knowledge that the drag effect was underestimated. Pilots from ATR, Empire Airlines, and the NTSB participated in the EFS qualitative testing.

1.16.1.1 Effects of Flap Asymmetry

The flap asymmetry involved 8° to 10° of extension of the left flap and no extension of the right flap. The greater flap extension on the left wing resulted in more lift and drag on that wing; as a result, the airplane banked to the right. According to the FDR, the autopilot system countered the airplane's right bank by introducing 6° of left aileron input, for which the autopilot moved the control wheel about 20° to the left.

The FDR indicated that, at 0434:55 (about 30 seconds after the flap asymmetry occurred), the first officer reduced engine power from about 58 percent torque to about 3 percent. The autopilot, which was coupled to the ILS 17R approach, responded by increasing the pitch attitude of the airplane to maintain the glideslope for the approach. The airplane's airspeed decreased to the point that, at 0435:30, the stick shaker activated, which disconnected the autopilot when the airplane was about 1,000 feet agl. The performance study showed that the stick shaker triggered at about an AOA of 7.2°, a load factor of 1.08 G, and an airspeed of 125 kts.

The FDR indicated that, after the autopilot disconnected (and the first officer began to manually fly the approach), the first officer increased engine power to about 70 percent torque, and the airplane began to deviate high and to the right of the ILS 17R glidepath.[39] Control force

[37] The study results are estimates that include performance calculation assumptions and consider the inherent limitations of the input data sources.

[38] Title 14 CFR Part 60, which contains the qualification performance standards for airplane EFS models, specifies that the effects of airframe icing (including airspeed decay and change in simulator pitch attitude) can be based on subjective tests; that is, an EFS's presentation of these effects is not required to match actual airplane performance data obtained from airplane icing testing, incidents, or accidents.

[39] The glidepath, which is the ideal flightpath for an ILS approach, is formed by the intersection of localizer plane (which provides horizontal course guidance along the extended runway centerline) and glideslope plane (which provides vertical course guidance).

estimates that ATR provided indicated that the first officer was applying about 35 to 40 lbs of rudder pedal pressure. ATR estimated that the average control wheel force required to manually counter the flap asymmetry without retrimming the airplane was about 13 lbs.

At 0435:50, the captain took control of the airplane, and the estimated pilot forces exerted on the cockpit controls peaked about 10 seconds later when the captain pulled back on the control column, input LWD control wheel, and pushed on the left rudder pedal. ATR estimated that the maximum forces exerted on the control column, control wheel, and rudder pedals were about 36, 29, and 112 lbs, respectively. The FDR indicated that, at the time that these maximum forces were applied, the airplane was about 500 feet agl and more than 300 feet right of course (in the cockpit, this position would have displayed as "two dots" right on the course deviation indicator),[40] and the stick shaker activated again. The performance study showed that the stick shaker triggered at about an AOA of 6.8°, a load factor of 1.64 G, and an airspeed of 155 kts.

FDR data indicated that, at 0436:02 (about 2 seconds after the captain's application of high control forces), the control wheel and the ailerons moved from the deflected positions that compensated for the flap asymmetry to their nominal positions. This movement was consistent with the left-wing flaps retracting to approximately 4.5°, and the right-wing flaps extending to approximately 4.5°, rendering all four wing flap panels symmetric, thus removing the need for control inputs to counteract the flap asymmetry.

1.16.1.2 Effects of Airframe Ice Accretion

FAA inspectors who observed the wreckage about 3 hours 20 minutes after the accident noted that the separated outboard section of the right aileron (which was found outside the fire area) had an 8-inch patch of 1/8-inch thick ice adhered to the underside. The adhered ice patch had jagged edges, as if some portions of ice had broken away from it. As noted in the *Aeronautical Information Manual* (AIM),[41] section 7-1-21, "the effects of ice on aircraft are cumulative; thrust is reduced, drag increases, lift lessens, and weight increases. The results are an increase in stall speed and a deterioration of aircraft performance."

The NTSB's aerodynamic coefficient extraction and calculations made by ATR indicated that airframe ice accretion during portions of the flight degraded the airplane's performance. The ATR calculations indicated that the airplane first encountered icing at the beginning of cruise flight at flight level (FL) 180 (18,000 feet pressure altitude). ATR calculated that, at the end of cruise flight at FL 180, a drag increase corresponding with about 15 percent of total power was present. The aerodynamic coefficient extraction showed an increment in drag beyond the level expected for an uncontaminated airframe from about 0335 to 0405 while the aircraft was in cruise flight.

The ATR calculations indicated that, during the descent between 14,000 to about 5,000 feet msl, the airplane's performance was consistent with what would be expected for an

[40] Course sensitivity at this point in the approach is such that one dot represents about 150 feet of horizontal course deviation.

[41] Information obtained from the FAA's website <http://www.faa.gov/air_traffic/publications/ATpubs/AIM/> (accessed March 21, 2011).

uncontaminated airframe (free from ice accumulation). The aerodynamic coefficient extraction showed the drag level expected for an uncontaminated airframe from about 0405 to about 0432. However, beginning about 0432 when the aircraft was at 5000 feet msl, an increment in drag beyond the level expected for an uncontaminated airframe was again seen. ATR calculated that, by the time that the flap asymmetry occurred, a drag increase corresponding with about 23 percent of total power was present. The EFS qualitative testing revealed that, following the autopilot disconnect, the workload for the accident flight crew was high because of the flap asymmetry, a 10-kt tailwind, and ice accretion. The testing showed that, when the approach was continued without retrimming the airplane and at a speed lower than the minimum safe airspeed of 143 KIAS (conditions similar to the accident flight), the controllability of the simulator was often similar to what the FDR data showed for the accident airplane. However, when the "AILERON MISTRIM" checklist in the Empire Airlines' ATR quick reference handbook (QRH) was applied[42] and engine power was set to maintain the minimum safe airspeed, the pilots who conducted the EFS qualitative testing performed a missed approach (go-around procedure when under IFR), completing the QRH procedures for the flap anomaly and the reduced-flaps landing, and successfully landing the airplane.

FDR data indicated that, at 0436:18 (about 9 seconds before impact), the captain began a pull back on the control column that lasted for several seconds. When the pull back began, the airplane was at an airspeed of about 125 kts, descending through 230 feet agl about 1,500 feet per minute (fpm); the pitch attitude was about -0.5°, and the load factor was about 0.9 Gs. In response to the captain's pull on the control column, the pitch attitude, the AOA, and the load factor all began to increase. The performance study showed that when the stick shaker triggered for the third time at 0436:19, the AOA was about 7°, the load factor was about 1.02 G, and the airspeed was about 124 kts.

At 0436:20 (about 7 seconds before impact), with the AOA and the pitch attitude still increasing, the load factor stopped increasing about 1.12 Gs, indicating that an aerodynamic stall was imminent.

1.16.2 Terrain Awareness and Warning System

The airplane was equipped with a TAWS[43] designed to provide terrain caution alerts, "pull up" warnings, and "avoid terrain" warnings. Data analysis showed that, when the TAWS provided the flight crew with the aural "pull up" warnings, the airplane was about 1.5 miles from the runway threshold at an altitude of 488 feet agl (as detected by the radio altimeter) with a vertical descent rate of 2,050 fpm. An event analysis report provided by Aviation Communication & Surveillance Systems, the manufacturer of the integrated system with the TAWS feature, indicated that, during the accident approach, the airplane's low radio altitude combined with the rapid change in vertical speed resulted in the immediate TAWS warning without a preceding caution alert.

[42] For information about the procedure, which involves retrimming the airplane and then reengaging the autopilot, see section 1.17.1.5.

[43] This particular TAWS was part of an integrated system that also provided traffic alert and collision avoidance functions.

1.16.3 Flap System Component Examinations

The cockpit flap control lever was found in the 15° position. Examination of the flap system components at the accident site found that the left wing and flap components were intact and covered with soot. The right inboard and outboard flaps and the right inboard flap actuator were extensively damaged by impact and fire. Figure 6 is the right side of the fuselage, showing extensive fire damage to the right wing and flap components. The right outboard flap actuator was found in the retracted position on the ground under the right wing. Damage to the right flaps limited the extent to which preimpact system integrity could be determined. Examination of the available components revealed no evidence of mechanical restriction of movement of the right flaps.

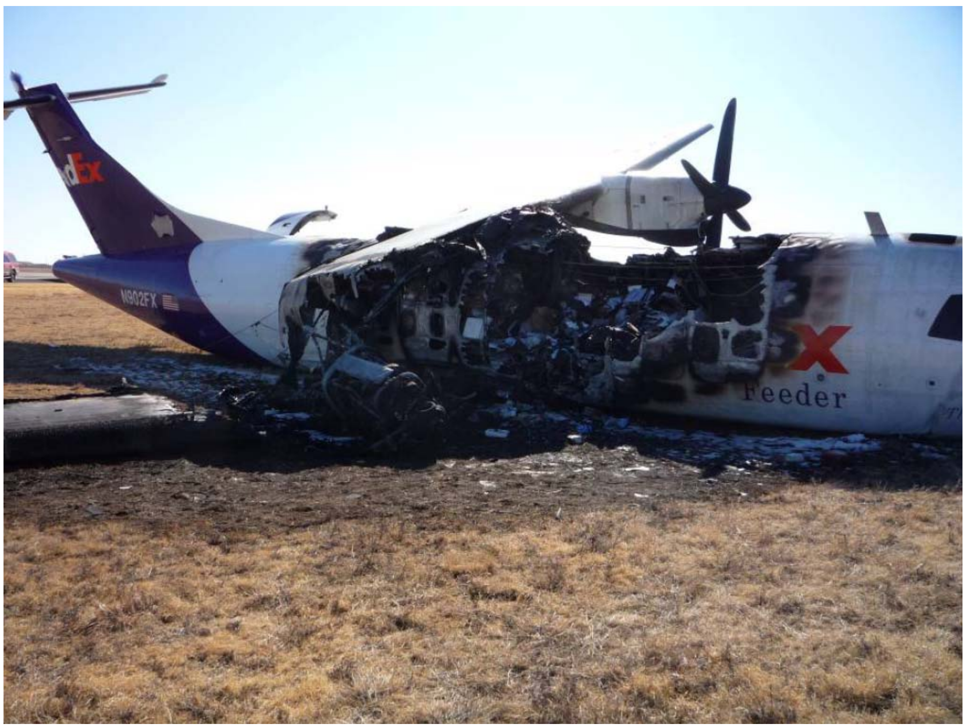

Figure 6. Right side of fuselage showing extensive fire damage to right wing and flap components.

Under normal circumstances, hydraulic pressure holds the flaps in the selected position. The accident airplane's hydraulic system was damaged by impact and fire, and much of the hydraulic fluid routed to the flap actuators was lost because of the damage. Testing of fluid samples obtained from all actuators (either from the actuator itself or the line leading to the actuator) found that the liquid was consistent with hydraulic fluid.

X-ray examinations of all four flap actuators showed that their internal components were in place. The left inboard and left outboard flap actuators functioned when tested on the test bench at the manufacturer's facility. Subsequent disassembly and examination of the left inboard and outboard flap actuators revealed no anomalies. Several of the seals for the right inboard and right outboard flap actuators were damaged from fire exposure, and the damage prevented the actuators from functioning on the test bench. Disassembly of the right inboard and outboard flap actuators revealed no evidence of jamming.

Regarding the possibility that ice formation on the flap surfaces could have resulted in a flap asymmetry, ATR stated that, in all types of icing conditions, runback icing does not exceed 15 to 20 percent of the wing chord on the upper wing surface and 30 to 40 percent of the wing chord on the lower wing surface and that these limits are upstream of the flaps. Further, ATR noted that ATR models having a similar wing/flap design have accrued 17,567,000 flight cycles with no reports of flap asymmetry or jamming due to flight in icing conditions.

1.16.3.1 Hydraulic Fluid Testing

The piston rod for the right outboard flap actuator was found coated with a green material for which chemical testing was inconclusive. Solid particles, which testing found to be consistent with heated hydraulic fluid, were found in the hydraulic fluid lines and the connector port for the right outboard flap actuator. No similar particles were found in any fluid samples from the airplane's hydraulic reservoir or from the examined hydraulic system filters.

1.16.3.2 Maintenance History

According to ATR, flap actuators are not subject to time limitations; they are serviced or replaced based on their condition. At the time of the accident, the right inboard flap actuator and the left outboard flap actuator were original equipment to the airplane (installed when it was manufactured). The right outboard flap actuator and the left inboard flap actuator were installed in February 2001.

Empire Airlines' maintenance records indicated that a flap actuator hardware inspection was completed on June 4, 2007. On October 31, 2007, during a takeoff configuration test performed during taxi, the flaps did not extend but then functioned normally after subsequent maintenance action to clean deicing fluid from the cannon plug. The airplane had been involved in a January 21, 1998, accident in which a fuel-fed fire erupted in the right engine bay after landing, which substantially damaged the airplane and exposed several components on the right wing, including the flaps, to fire damage.[44] The airplane's log books showed that the airplane had been repaired, inspected, and returned to service.

1.16.3.3 Flap Asymmetry Event Involving Another Airplane

According to ATR, one previous flap asymmetry event was reported in 1996 involving an ATR 42-500. The event occurred during a maintenance positioning flight (the maintenance was related to a problem with the right powerplant that occurred on the previous day). During the positioning flight, the asymmetry occurred when the flight crew commanded flap extension. The airplane landed without incident, and the reason for the flap asymmetry was not determined.

[44] The NTSB determined that the probable cause of the accident was "the improper overhaul of lug holes on the fuel/oil heat exchanger. A factor was the lack of direction contained in the manufacturer's overhaul manual for working with the lug holes." The report for this accident, NTSB case number NYC98FA062, is available online at <http://www.ntsb.gov/aviationquery/index.aspx>.

1.16.4 Deicing and Anti-Icing System Examinations

The pneumatic deicing boots on the left wing and the empennage were tested, and no preimpact anomalies were identified. Impact and fire damage to the pneumatic boots on the right wing prevented testing. The distributor valves for the airframe pneumatic boots were tested, and all of the valves opened and closed as designed. All electrically heated components were examined, and a resistance was obtained. Examination of the AAS annunciator panel by the NTSB's materials laboratory revealed no evidence of filament stretching in any bulbs.

1.16.5 Autopilot Disconnect Alert

The crew alerting computer, flight guidance computer, flight guidance controller, and ADU were tested after the accident, and the autopilot disconnect and alerting systems functioned normally. The autopilot disconnect aural alert sounded as designed. According to ATR, the control wheel is equipped with an autopilot disconnect push button. Pressing the button while the autopilot is engaged disconnects the autopilot. Pressing the button while the autopilot is disconnected (whether disconnected manually with the button or by stick-shaker activation) clears any messages from the ADU and silences any pending autopilot disconnect alert.

1.17 Organizational and Management Information

Empire Airlines, headquartered in Hayden, Idaho, provides cargo operations under 14 CFR Parts 135 and 121. The company, which has evolved under different names and has provided a variety of services (including some passenger-carrying operations) since 1977,[45] began Part 121 operations in 1989. During that same year, Empire Airlines began a contract with FedEx for cargo services using Fokker F27 airplanes. The company continued to evolve its fleet and services and ended all passenger-carrying operations in 1995 to focus on cargo operations, aircraft maintenance, and airline startups.[46] The company obtained a 14 CFR Part 145 repair station certificate under the name of Empire Aerospace in 2001. It acquired its first ATR 42 airplane in 2003 and performed its first ATR 42 revenue flight for FedEx in 2004.

At the time of the accident, Empire Airlines had 16 bases of operation and served 51 destinations as a feeder operator for FedEx. According to the managing director of FedEx feeder operations, FedEx's relationship with its feeder operators is a fee-basis system in which

[45] The company was first established as Clearwater Flying Service in 1977 and, by 1979, operated flights for fire patrol, air pollution monitoring, air ambulance, charter, flight instruction, and transporting outfitters to remote areas. In 1980, after acquiring another company, Clearwater Flying Service changed its name to Empire Airways and expanded its services to include aircraft sales and maintenance. In 1986, the company contracted to operate shuttle flights between ski resorts, and, in 1987, the company expanded with contracts to fly corporate employees between offices in California and to perform flights in Alaska for the Naval Arctic Research Laboratory. Later that same year, Empire Airways contracted with FedEx to fly and maintain Cessna 208 airplanes and to service routes throughout the Pacific Northwest. In 1989, Empire Airways purchased Pacific Alaska and two Fokker F27 airplanes, and the company changed its name to Empire Airlines.

[46] Empire Airlines added turbojet airplanes for some operations in 1992. The company also assisted a startup airline in Hawaii in 1992 and assisted another airline in Europe (to provide services for FedEx) in 1998. In 2006, the company's operations specifications authorized it to perform heavy maintenance on ATR 72 and Fokker F27 airplanes, and it later obtained heavy maintenance authorizations for de Havilland DHC-8 and Q400-series airplanes.

the operators are paid a management fee to crew and maintain the airplanes. At the time of the accident, Empire Airlines operated 10 ATR 42, 3 ATR 72, and 35 Cessna 208 airplanes, all of which were owned by FedEx. Empire Airlines employed about 250 people, including 108 pilots, 34 to 40 mechanics, and 7 flight followers.

1.17.1 Pilot Standard Operating Procedures and Training

Empire Airlines' general operations manual (GOM) provided flight crews with information on the company's standard operating procedures (SOPs). Flight crew procedures specific to the airplane were found in the ATR 42 AFM, which was an FAA-approved manual that contained the normal, abnormal, and emergency procedures. The Empire Airlines ATR 42 QRH listed the procedures in a cockpit checklist format.

Empire Airlines provided its pilots with company indoctrination training at company headquarters. Empire Airlines' operations specifications authorized that all other initial, recurrent, upgrade, and transition ground training, simulator training, testing, and checks were to be provided by FlightSafety International, Inc., in Houston, Texas.

1.17.1.1 Flap Anomalies

According to the QRH, one procedure covered multiple flap anomaly conditions, including a jam, uncoupling, or asymmetry. The procedure, "FLAPS JAM/UNCOUPLED/ASYM," specified that the pilot should position the flap control lever to correspond with the actual flap position and apply the "REDUCED FLAPS LANDING" procedure. Figure 7 is the QRH, page 2.21, with "FLAPS JAM/UNCOUPLED/ASYM" and "REDUCED FLAPS LANDING" procedures. Pilots are trained to perform a go-around maneuver in response to a flap anomaly so that they will have time to perform these required procedures.

Empire AIRLINES ATR42 QUICK REFERENCE HANDBOOK

2 FOLLOWING FAILURE – FLIGHT CONTROL

FLAPS UNLK

■ **If before V1**
TAKE OFF .... ABORT
■ **If after V1**
VR, V2 .... INCREASE BY 10 KT
■ **If alarm occurs during approach**
GO AROUND procedure .... APPLY
VGA .... INCREASE BY 10 KT

● **When possible**
FLAPS 0
REDUCED FLAPS LANDING procedure (2.21) .... APPLY

FLAPS JAM / UNCOUPLED / ASYM

FLAPS CONTROL LEVER .... NEAR FLAPS PRESENT POSITION
● **When applicable**
REDUCED FLAPS LANDING procedure (2.21) .... APPLY

REDUCED FLAPS LANDING

GPWS .... GPWS OVRD or FLAP OVRD (depending on version)
STEEP SLOPE APPROACH (≥4.5°) .... PROHIBITED

FLAPS	LDG DIST FLAPS 30 MULTIPLY BY	APP SPEED	LDG SPEED
0	1.30	VmHB 0 + WIND EFFECT	VmLB 0 + WIND EFFECT
15	1.15	VmHB 15 + WIND EFFECT	VmLB 15 + WIND EFFECT

Note: Refer to Part 4 to determine VmHB, VmLB and LDG DIST.
Caution: Tail strike may occur if pitch attitude exceeds 10° during the flare depending upon vertical speed at touchdown.

STICK PUSHER / SHAKER FAULT

STICK PUSHER / SHAKER .... OFF
TCAS .... TA ONLY
VmHB/VmLB FOR ALL CONFIGURATIONS .... INCREASE BY 10 KT
LDG DIST .... MULTIPLY BY 1.13
Note: Refer to Part 4 to determine VmHB, VmLB and LDG DIST.

Page 2.21 Rev. 5 09/10/08

Figure 7. Quick reference handbook page 2.21 with “FLAPS JAM/UNCOUPLED/ASYM” and “REDUCED FLAPS LANDING” procedures.

According to the GOM, section 6-19, “Completion of Non-Normal Cockpit Checklist,” flight crews are instructed that, “in the event of inoperative or malfunctioning flight control system, if the airplane is controllable, complete only the applicable checklist procedures and do not attempt any corrective action beyond those specified.” The GOM, section 6-4, “Circuit Breakers Resetting,” stated that “tripped circuit breakers should not be reset in flight unless, in the judgment of the PIC, it is necessary for the safe completion of the flight.”

The QRH, page 0.02 (directly beneath the Table of Contents), states the following general information under the heading, “Procedures Initiation”:

> … No actions will be taken…until the flight path is stabilized… . Before performing a procedure, the crew must assess the situation as a whole, taking into consideration the failures, when fully identified, and the flight constraints imposed.

Page 0.02 of the QRH also states that the PF is responsible for the engine power levers, flightpath and airspeed control, aircraft configuration, and navigation, and the PM is responsible for completing the appropriate checklist items, the actions on the overhead panel, the positioning of the condition levers (which relate to propeller control), and communications. Figure 8 shows the general information on page 0.02 of the QRH.

If this page is printed, it is for reference only.

Empire AIRLINES ATR42 QUICK REFERENCE HANDBOOK

[0] GENERAL

TABLE OF CONTENTS

[0]— General
[1]— Emergency Procedures
[2]— Following Failures
[3]— Normal Procedures
[4]— Ops Data (Two section 4s, one for PW120 and one for PW121)
[5]— LEP/Revisions

COMMENTS ABOUT CHAPTERS 1 & 2

Layout

- ■ highlights a precondition to apply an action
- ● indicates the moment when an action is to be applied

PROCEDURES INITIATION

1. No actions will be taken (apart from depressing MC / MW pb):
   - Until flight path is stabilized
   - Under 400 ft above runway, except propeller feathering after engine failure during approach at reduced power if go around is considered, or engine failure during takeoff when autofeather does not function and aircraft control or climb is in doubt.
2. Before performing a procedure, the crew must assess the situation as a whole, taking into consideration the failures, when fully identified, and the flight constraints imposed.
3. At flight crew discretion and after consulting the QRH procedure for the identified failure, one reset of a system failure associated with an amber caution may be performed by selecting the related push button OFF then ON. If the failure alert disappears, continue normal operation. If not, apply the associated failure procedure.

TASK SHARING

For all procedures, the general task sharing stated below is applicable. The pilot flying remains pilot flying throughout the procedure.

PF — Pilot flying responsible for:

- PL
- Flight path and airspeed control
- Aircraft configuration
- Navigation

PNF — Pilot non flying responsible for:

- Checklist reading
- Execution of required actions
- Actions on OVHD panel
- CL
- Communications

The AFCS is always coupled to the PF side (CPL selection)

ANALYSIS OF CONSEQUENCES OF A FAILURE ON THE FLIGHT

Basic airmanship calls for a management review of the remaining aircraft capabilities under the responsibility of CM1.

Page 0.02 Rev. 3 10/16/06

Figure 8. General information on page 0.02 of quick reference handbook.

Both the captain and the first officer received training on flap anomalies during ground school and simulator training at FlightSafety. The flap system anomalies that were covered during ground school training included flap jam, flap unlock, flap uncoupled, flap asymmetry, and no flaps. Flap control circuit breakers were discussed. The ground training reviewed the QRH for flap anomalies item by item. For a flap asymmetry, the training taught the pilots that the airplane will try to roll, which requires the pilot to take the controls. During simulator training, flap anomalies were covered as part of both initial and recurrent training. The type of anomaly was given at the discretion of the instructor (the syllabus did not specify which anomaly to present). Pilots were trained to look at the flap position indicator in the cockpit, and they were also taught to look out the side windows at the flap position fairings to verify the flap conditions.[47]

The NTSB interviewed FlightSafety instructors who stated that, regardless of which anomaly was presented and when, the response procedure was the same. The pilots were taught to initiate a go-around maneuver and complete the QRH, which required them to rebug the airspeeds for the flap setting that they had. During postaccident interviews, the FlightSafety instructors, the FAA principal operations inspector (POI) for Empire Airlines, Empire Airlines' chief pilot, and Empire Airlines' director of operations indicated that they would have expected the accident flight crew to use the QRH procedure in response to the flap anomaly. During subsequent testimony at an NTSB public hearing,[48] Empire Airlines' chief pilot and director of operations both stated that they would have expected the flight crewmembers to first assess the situation and then reference the QRH after identifing the problem.

FlightSafety did not train pilots to troubleshoot a flap anomaly by checking the circuit breakers, and none of the instructors who were interviewed had ever observed a trainee attempt to do so in the flight simulator. One instructor could not recall any pilots ever attempting to land with a flap abnormality during training and stated that it was "drilled into their heads to go around" if a flap problem occurred.

During postaccident interviews and public hearing testimony, the captain stated that he checked the cockpit flap position indicator and determined that the flaps had not extended. He also stated that he attempted to troubleshoot the flap problem by checking the circuit breakers because he "had to start somewhere" and that he needed to determine what the malfunction was and then handle it with the checklist. The captain stated that he did not follow the abnormal procedures checklist for the flaps because the airplane was on a short final approach, things were happening quickly, and he "was too busy and did not know which checklist to run first or the speeds."

During postaccident interviews and public hearing testimony, the first officer stated that she did not know there was a flap asymmetry and thought they had no flaps. She further stated that she was "a little bit" concerned about the captain's use of a flashlight to look at the circuit breakers during the approach. She also stated that she thought he should have been more focused on landing the airplane. The first officer stated that, had they executed a missed approach, they

[47] Verifying the flap conditions was simulated in training as there were no actual flap position fairings in the simulator.

[48] For more information about the public hearing, see Appendix A.

would have had time to use the QRH, get situated, and set their airspeeds. The first officer stated that, after the captain decided that the approach would be continued, there was not enough time to use the QRH.

1.17.1.2 Stabilized Approach and Go Around

Empire Airlines' ATR 42 pilot handbook and flight training manual (FTM) both addressed stabilized approach criteria and approach standardization procedures. According to the FTM, approaches conducted in IMC should be stabilized by 1,000 feet in height above touchdown, and approaches conducted in visual meteorological conditions (VMC) should be stabilized by 500 feet in height above touchdown.

The FTM listed several criteria for the flight crew to determine that an approach would be considered stabilized. These criteria included (but were not limited to) ensuring that only small changes in heading and pitch are needed to maintain the correct track, the rate of descent deviates no more than plus or minus 300 fpm from the target descent rate, the airplane's airspeed is not less than the required approach speed, the maximum sink rate does not exceed 1,000 fpm (a special briefing should be performed for any approach requiring a greater sink rate), the power setting is appropriate for the configuration, and all briefings and checklists had been performed.

According to the ATR 42 pilot handbook, "Flight Profiles & Briefings," the "Descent and Approach Awareness Procedures" indicated that, during an ILS approach, the PM is to "call out any deviations from normal altitude, airspeed, or descent rates throughout the approach." The procedures noted that the "captain calls for 'missed approach,' if necessary." The pilot handbook, section 2-02-04, stated that, if a go-around maneuver is required, the PF should initiate the procedure by calling out "go around," pressing the "GA" (go around) button on the engine power levers, advancing the engine power levers toward the white mark, and calling out "max power, flaps 15."

FlightSafety instructors who were interviewed stated that stick-shaker activation meets the criteria for an unstabilized approach. During postaccident interviews, the captain stated that he was trained to go around if a problem occurs during approach and that his decision to continue the approach was based on the runway conditions,[49] icing conditions, and the flap problem. The captain stated that he "made a judgment call not to go around because things started piling up, and it was better to land than to go around." He stated that he "just wanted to land as soon as possible."

During a postaccident interview, the first officer stated that stick-shaker activation "would be a go-around situation" and that she asked the captain about going around because the company policy following stick shaker was to perform a go-around maneuver. The first officer

[49] According to the CVR transcript, the LBB approach controller advised the flight crew that the Mu readings (friction coefficient values taken by runway friction-measuring equipment) for runway 35L at touchdown, midpoint, and rollout were .24, .25, and .23, respectively. The captain acknowledged and then advised the first officer that, during landing, she should keep the airplane on the runway centerline and not touch the brakes. Empire Airlines' GOM (section 6-12, revision 43) provided a table that "converts braking action reports to friction coefficient values" and showed that Mu readings between .19 and .34 corresponded with a "poor" braking action report. The GOM also stated that "there is no direct correlation between friction coefficient values and braking action" and that flight crews should use the values "together with other knowledge, including recent braking action reports and wind conditions."

indicated that asking was her way of saying that she wanted to go around “without stepping on toes.” The first officer further stated that she did not challenge the captain’s decision to continue because she felt that he had a good reason for not wanting to go around and that she trusted that he was making the right decisions. The first officer also stated that, after the captain took control of the airplane, she thought that she should have suggested again that they go around and that she did not know why she did not say anything.

1.17.1.3 Terrain Awareness and Warning System

According to the GOM, if the flight crew receives a TAWS caution alert or warning in conditions other than daylight VMC (in which the flight crew can positively confirm that a collision with the terrain will not take place), the flight crew is to “react immediately.” The procedures for responding to a “pull up” warning stated that the flight crew is to advance to go-around power, disconnect the autopilot, level the wings while simultaneously executing a positive pull up, set flaps to the go-around position, retract the landing gear, and maintain the specified minimum airspeed until terrain clearance is assured.

1.17.1.4 Airspeed Bugs

As described in section 1.6.4.1, Empire Airlines’ ATR 42 pilot handbook stated that, for an approach in icing conditions, the flight crew should set the internal, yellow, white, and red bugs to correspond with the $V_{mHB}30$ icing, V_{ga}, $V_{mLB}0$ normal, and $V_{mLB}0$ icing airspeeds, respectively. Flight crews were provided with an ATR 42 V-speed card pack that provided the applicable minimum approach airspeeds based on the airplane’s weight. The same card that provided approach airspeeds for each referenced airplane weight also provided airspeeds for use during takeoff. The guidance provided to flight crews on setting the airspeed bugs did not include any crosscheck procedures for verifying the information.

Postaccident examination of the cockpit found that the V-speed card pack was open to the reference card for an airplane at 33,000 lbs gross weight. This card showed that, for this airplane gross weight in icing conditions, $V_{mHB}30$ was 116 kts, $V_{mLB}0$ normal was 123 kts, and $V_{mLB}0$ icing was 143 kts. V_{ga} was not depicted on the card. According to the ATR 42 pilot handbook, V_{ga} is computed based on the normal approach airspeed (by either adding 5 kts to $V_{mHB}30$ or using 1.1 V_{mca}, whichever is greater). Based on the card information, the approach airspeeds for setting the internal, yellow, white, and red bugs were 116, 121, 123, and 143 kts, respectively, and the takeoff airspeeds for setting the internal, yellow, white, and red bugs were 106, 112, 123, and 143 kts, respectively.

According to the CVR transcript, during the captain’s approach briefing, he referenced the “three thirty card” and read “one oh six [106 kts] is the icing speed…one oh six [106 kts] one twelve [112 kts]…uh twenty three [123 kts] and forty three [143 kts].” Postaccident examination of the captain’s and first officer’s airspeed indicators found that the captain’s internal, yellow, white, and red bugs were set to 109, 110, 124, and 145 kts, respectively, and that the first officer’s were set to 106, 112, 126, and 144 kts, respectively.

1.17.1.5 Aileron Mistrim with Autopilot Engaged

With the autopilot system engaged, the roll anomaly induced by a flap asymmetry will generate “RETRIM ROLL R [or L] WING DN” and “AILERON MISTRIM” messages on the ADU. According to the manufacturer, a flight crew’s response to these messages should be to hold the control wheel firmly, disengage the autopilot, and adjust the lateral trims. Upon completion of these items, the autopilot may be reengaged. The AFM stated that, since the autopilot may mask tactile cues that indicate adverse changes in airplane handling characteristics, use of the autopilot is prohibited when unusual lateral trim requirements or autopilot trim warnings are encountered when the airplane is in icing conditions.[50] During postaccident interviews, both the captain and the first officer indicated that they did not see any messages on the ADU.

1.17.1.6 Deicing and Anti-Icing Systems

The AFM defined three levels of icing equipment use and stated that level 3 protection, which the flight crew used during the accident descent, should be used any time that ice is observed accumulating on the airframe. According to the AFM, level 3 icing protection includes all level 1 and 2 items, plus the use of continuous relight engine ignition and the airframe pneumatic deicing boots.[51] Flight crew selection of the flight control horn anti-icing system (used in level 2 and 3 ice protection) lowers the AOA stall warning threshold and triggers the illumination of the green ICING AOA annunciator. Once airframe pneumatic boot use is selected by the flight crew (by pushing the “AIRFRAME” button), the boot system inflates in sequence continuously without further crew input.

According to the FCOM, the AAS’s amber ICING annunciator illuminates as soon as (and as long as) the system’s ice detector senses that ice is building up. The flight crew was trained to respond to AAS annunciators in the cockpit by increasing the minimum maneuvering and operating airspeeds and selecting the anti-icing system when flying in icing conditions, selecting the deicing system at the first indication of airframe ice accumulation, and switching the deicing system off once ice is no longer present on the airframe. Once the ice detector no longer senses that ice is accumulating, the system triggers the blue DEICING annunciator to flash, alerting the flight crew to visually check for the absence of ice and determine if the deicing system should be turned off.

The FCOM cautions that freezing rain is composed of SLD that may transform into clear ice when it impacts the airplane’s skin in below-freezing temperatures. The FCOM states that these large droplets may not freeze immediately upon impact and that the ice detector may become “inefficient” (ineffective). According to ATR’s *Cold Weather Operations* publication,[52]

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[50] The AFM also stated that use of the autopilot is prohibited any time that severe icing exists.

[51] Level 1 protection, which was to be used during all flights, included use of the probe heat and windshield heat. Level 2 protection, which was to be used for all takeoffs and all flight operations in atmospheric icing conditions, included the level 1 items plus the use of propeller, flight control horn, and side window heat; engine inertial separators and pneumatic boots; minimum propeller speed of 86 percent; illumination of the AOA light; and icing speeds bugged and observed.

[52] ATR Flight Operations Services, *Cold Weather Operations: Be Prepared for Icing* (2008). This publication was updated in March 2011, and the current edition can be obtained from ATR’s website

flight crews can visually assess ice accumulation by observing the propeller spinners, windshield, airframe leading edges, wipers, and side windows.

According to the AFM limitations, section 4-5, if severe icing conditions are encountered in flight, the flight crew's procedures include escaping the severe icing conditions and notifying ATC. According to the AFM,

> severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle, or mixed icing conditions (supercooled liquid water and ice crystals) may result in ice buildup on protected surfaces exceeding the capabilities of the ice protection system or may result in ice forming aft of the protected surfaces.

The AFM states that the visual cues to identify severe icing include "ice covering all or a substantial part of the unheated portion of either side window," and/or an "unexpected decrease in speed or rate of climb," and/or the following secondary indications:

- Water splashing and streaming on the windshield.
- Unusually extensive ice accreted on the airframe in areas not normally observed to collect ice.
- Accumulation of ice on the lower surface of the wing aft of the protected area.
- Accumulation of ice on the propeller spinner farther aft than normally observed.

In a postaccident interview, the captain stated that the airplane had encountered "moderate bordering on severe" rime ice at FL 180. He stated that he selected level 3 ice protection and that he noticed that, during the icing encounter, the airplane was cruising at 180 KIAS, whereas it would typically cruise at 200 to 210 KIAS. He stated that he requested a descent to 14,000 feet msl and that, during the descent, "substantial amounts of ice" came off the airplane. He noted that some ice from that encounter was still on the airframe when the flight started its descent to LBB. Further, in a postaccident interview, the first officer stated that the airplane began to accumulate ice again as it descended through 6,000 feet msl. She recalled that level 3 ice protection had been activated and that she could see ice adhering on the propeller spinner.

1.17.1.7 Crew Resource Management

CRM is the effective use of all available resources, people, information, and equipment to achieve safe and efficient flight operations.[53] CRM involves crewmembers incorporating and synchronizing the tasks required of them in a correct and timely manner[54] and communicating

<http://www.atraircraft.com/content/media/downloads/coldweatheroperations_2011_20.pdf> (accessed April 14, 2011).

[53] J. Lauber, "Resource Management in the Cockpit," *Air Line Pilot*, vol. 53 (1984), pp. 20-23.

[54] J.A. Cannon-Bowers Volpe and others, "Defining Team Competencies and Establishing Team Training Requirements," in R. Guzzo, E. Salas, & Associates, eds., *Team Effectiveness and Decision Making in Organizations* (San Francisco: Jossey-Bass, 1995), pp. 333-380.

and coordinating effectively. FlightSafety provided CRM training to Empire Airlines' crewmembers during initial training, and CRM was reviewed during recurrent training.

The CRM training provided during the pilots' initial training consisted of 2 days (16 hours) in the classroom and included lectures, case study reviews, and breakout and team building sessions with crewmembers. Lecture topics included command and leadership, situational awareness, communication, decision making, error management, teamwork and synergy, fatigue, risk assessment, and automation management. The CRM training materials included two presentation slides on assertion that encouraged pilots to speak up with "appropriate persistence until there is a clear resolution." The FlightSafety ATR program manager stated that Empire Airlines' CRM training program did not include role-playing exercises in the classroom training. During a postaccident interview, the first officer stated that she could not recall what was presented during the 2-day CRM training course, including whether or not assertiveness was addressed.

According to Empire Airlines' FTM, the CRM review provided during recurrent training was included within the "Crew Duties and Responsibilities" module and in "Flight Module 1." According to Empire Airlines' FTM, section 8-1-6, applied CRM is monitored and practiced in each flight simulator module. One FlightSafety instructor stated that CRM was evaluated throughout the simulator training because the ATR 42 is a two-pilot airplane, and he stated that he would point out CRM issues in real time if he felt that it was necessary. Another instructor indicated that instructors had the tools and techniques to teach CRM during the prebriefing, in the simulator, and during the debriefing.

1.17.1.8 Weather Information and Training

Empire Airlines' chief pilot indicated that, during basic indoctrination training, pilots reviewed Empire Airlines' aircraft deicing program (ADP); the FAA's meteorology handbook; the National Aeronautics and Space Administration's (NASA) video, *Tailplane Icing*;[55] an operations in icing for corporate aircraft video; and handouts of flight releases to familiarize pilots with the format.

Empire Airlines' chief pilot also indicated his belief that, during training at FlightSafety, pilots reviewed the ATR *Cold Weather Operations* publication[56] and discussed meteorological conditions likely to cause freezing drizzle and freezing rain. Interviews with FlightSafety instructors revealed that several were familiar with the ATR publication but that none of the instructors provided or discussed it during training. A review of Empire Airlines' FTM revealed that it included a task-listing document that indicated that Empire Airlines (not FlightSafety) was

[55] The NASA video describes the tailplane stall condition that can result from horizontal stabilizer icing, its warning signs, and the suggested recovery procedures. The video's recovery procedures apply to airplanes that have unpowered controls, that is, airplanes with horizontal stabilizers that have a fixed leading edge and movable elevator surfaces that rely on aerodynamic balance to keep the control forces neutral. The ATR 42 is equipped with such unpowered controls (also known as reversible controls). All airplanes that are certificated under 14 CFR Part 25 have been tested for tailplane stall susceptibility under at least the Part 25, Appendix C, icing conditions and have demonstrated that they can be safely operated in such conditions. For conditions that are outside the Part 25, Appendix C, icing envelope, the performance and handling characteristics of the airplanes are not required to have been evaluated.

[56] *Cold Weather Operations: Be Prepared for Icing* (2008).

to provide the required training as part of the meteorology module, but Empire Airlines did not provide it.

A review of the ATR *Cold Weather Operations* publication[57] revealed that it provided guidance that advised pilots that icing is a major concern for commuter aircraft. The publication stated that, due to their typical operating altitudes and airspeeds, turboprop aircraft fly where icing conditions are most likely to occur. The publication also provided information about icing meteorological phenomena, aircraft systems available to prevent and control ice accumulation, aircraft performance loss due to ice contamination on the aerodynamic surfaces of the airplane, and the procedures to apply on the ground and during flight when faced with icing conditions.

1.17.1.9 Stall and Near-Stall Recoveries

A review of Empire Airlines' FTM revealed that company pilots were taught that at first stall indication,[58] they should set maximum power, reduce pitch, roll wings level, and then, during stall recovery, return to the entry altitude.

In June 2010, a stall recovery procedure was added to the ATR 42 AFM. The procedure, "RECOVERY AFTER STALL OR UNCOMMANDED ROLL CONTROL," specifies that the pilot should push firmly on the control wheel and then set maximum power.

1.17.2 Aircraft Deicing Program (Ground)

In accordance with 14 CFR 121.629, Empire Airlines had an FAA-approved ADP to address procedures for ensuring that no airplanes are dispatched or released for takeoff with unsafe frozen contaminants on their surfaces. The program conformed to the guidance in AC 120-60B, "Ground Deicing and Anti-Icing Program," which provides information on industry standards and practices related to ground deicing and anti-icing programs. The ADP contained holdover tables that provided guidelines on the amount of time that deicing and anti-icing fluid would protect an airplane's critical surfaces from frozen contaminants, such as active frost, freezing fog, snow, snow grains, freezing drizzle, light freezing rain, and rain on cold-soaked wings.

1.17.3 Flight Dispatch

Empire Airlines' flight dispatching functions were performed from the communications center at its headquarters. As a 14 CFR Part 121 supplemental air carrier, Empire Airlines was authorized to use flight followers (rather than licensed dispatchers) to authorize each flight release, provide the necessary preflight weather products, and perform flight following of the flight to the destination. All of Empire Airlines' flight followers (with the exception of one who

[57] *Cold Weather Operations: Be Prepared for Icing* (2008).

[58] As defined by Empire Airlines, the first indication of a stall is the recognition by the pilot of the stall warning aural "cricket," the stick shaker, the stick pusher, or buffeting/lateral instability.

was newly hired) were licensed dispatchers.[59] Flight followers communicated with flight crews through the use of telephones, fax machines, and air-to-ground communications services.

The flight release for the accident flight was issued about 0211 and listed Roswell International Air Center Airport, Roswell, New Mexico (located about 137 miles west of LBB), as the alternate airport. The weather document indicated that the aviation routine weather reports for LBB were reporting IFR conditions with light freezing drizzle and mist and that the aviation terminal forecast expected the IFR conditions and light freezing drizzle to continue beyond the estimated time of arrival. Several observations surrounding LBB also reported mixed freezing precipitation across the area and indicated that these were not isolated events. The document also contained the full AIRMET Zulu series (which pertains to icing) current over the area for occasional moderate icing conditions below 22,000 feet msl. The document indicated that the forecast for the Roswell International Air Center Airport expected wind from the north-northwest at 12 kts, visibility better than 6 miles, no precipitation, and a ceiling broken at 1,600 feet agl.

According to the GOM, section 8-9, "when light freezing rain, light or moderate freezing drizzle, or light, moderate or heavy snow is falling, aircraft may land." The GOM also stated that, "when light freezing rain, light to moderate freezing drizzle, or light, moderate snow is falling, [an ATR] aircraft may take off, provided it is prepared in accordance with approved deicing procedures."[60] Empire Airlines' director of operations stated that the airline developed this guidance using the titles from the ADP holdover tables after receiving flight crew requests for guidance related to operating in icing conditions.

During a postaccident interview, the flight follower who initiated preparations of the flight release for the MAF-to-LBB flight leg indicated that she was aware of the freezing drizzle conditions surrounding LBB. Another flight follower released the flight. The flight followers who handled the accident flight's release and the dispatch manager indicated that the GOM contained no restriction that prevented ATR airplanes from operating in light freezing drizzle and light freezing rain. All of them indicated that they believed that the ATR airplanes could handle light freezing rain and freezing drizzle conditions but that the Cessna 208 airplanes (which the flight followers indicated were prohibited from operating in those conditions) could not. Both the dispatch manager and one of the flight followers indicated that as long as the airplanes met the requirements for ground deicing, they could be released for flight.

During postaccident interviews, both the captain and the first officer stated that the company did not pressure them to depart or arrive on time. The flight follower who released the accident flight indicated that he had a "normal conversation" with the captain and that the weather conditions were not that bad compared to other weather he had seen over the years. The flight followers who were interviewed indicated that, if a captain disagreed with the flight followers, the flight followers typically backed up the captain's decision, and the captain had the final say. During public hearing testimony, Empire Airlines' manager of dispatch stated that if a

[59] Although the flight followers were licensed dispatchers, their duties were defined more closely with the role of flight follower and did not require the same initial and recurrent training that is required of a dispatcher.

[60] The GOM prohibited the company's Cessna 208 airplanes from departing, operating en route, or landing in freezing rain or freezing drizzle of any intensity.

captain was not comfortable launching due to weather, the flight follower would support the captain's decision.

A cursory review of other 14 CFR Part 121 and 135 operators' icing guidance (which included some operators that operated ATR or other turbine-powered, deice boot-equipped airplanes) revealed that the guidance ranged from prohibitive to permissive. For example, some guidance stated that "flight" or "takeoffs" in freezing rain and freezing drizzle was "not approved" or "prohibited"; other guidance warned that "flight in freezing rain [or] freezing drizzle…may result in ice buildup…exceeding the capability of the ice protection system" or that "visible rain at temperatures below 0° C" may be conducive to "severe in-flight icing"; and other guidance indicated that "aircraft may operate when light freezing rain [or] light to moderate freezing drizzle…is falling…provided that it is prepared in accordance with approved deicing procedures" or that "when light freezing rain [or] light or moderate freezing drizzle…is falling, aircraft may land."

1.17.4 Hazardous Materials

The GOM contains Empire Airlines' procedures related to HAZMAT cargo. Specifically, section 10-16 states that emergency response information (required in accordance with 49 CFR 172.600[c]) for use in mitigating an incident involving the HAZMAT cargo must be immediately available where the HAZMAT is received, stored, or handled during transportation and must be immediately available on board the aircraft. Section 10-17 indicates that, before departure, the PIC must be provided written information about the HAZMAT cargo, proper shipping name, hazard class, identification number, quantity, and location on board the airplane. The GOM states that a copy of the HAZMAT document provided to the PIC is subject to the following (in accordance with 49 CFR 175.33[c]):

> This information must be readily accessible at the airport of departure and the intended airport of arrival for the duration of the flight leg and [must be made…] immediately available to any representative of federal, state, or local government agency who is responding to an incident involving the flight.

1.17.5 Federal Aviation Administration Oversight

The FAA's flight standards district office (FSDO) in Spokane, Washington, provided oversight for Empire Airlines. The FSDO's oversight of Empire Airlines' 14 CFR Part 121 operations was managed through the FAA's air transportation oversight system (ATOS). According to the FAA, ATOS provides a means of oversight that allows air carriers to meet and address all regulatory requirements, enables FAA inspectors to develop methodology for continued operational safety, and provides FAA inspectors and air carriers the ability to manage risk. The ATOS oversight requirements included oversight of the content of an airline's manual and the training of the flight crewmembers.[61]

[61] ATOS oversight requirements are contained in FAA Order 8900.1, Flight Standards Information Management System, Volume 10, Chapter 1, Figure 10-7,"System/Subsystem/Element Chart—Operations and Cabin Safety Elements." Information obtained from the FAA's website <http://fsims.faa.gov/PICResults.aspx?mode=EBookContents> (accessed April 14, 2011).

The FAA POI for Empire Airlines had been assigned to the company for more than 11 years. He stated that the GOM was the FAA-approved manual and that the pilot handbook was "accepted." He stated that he was the POI for the company when operations in freezing drizzle were approved. He also stated that Empire Airlines had recently developed an internal audit program for flight operations. The POI described Empire Airlines as a company with good management people who self-report any problems.

The FAA principal maintenance inspector (PMI) for Empire Airlines had been assigned to the company since 2000. He described Empire Airlines as very cooperative, very responsive in correcting any identified problems, and consistent about submitting self-disclosures. The PMI stated that his work program had been managed through ATOS since October 2006. He stated that the ATOS process enabled him to develop the depth of inspection required.

1.17.6 Previous Accidents

The company had two previous fatal accidents in 1995 and 2000, both of which involved single-pilot cargo flights that were operated under 14 CFR Part 135. On January 11, 1995, a FedEx-owned Cessna 208 operated by Empire Airlines collided with a ridgeline in Pleasanton, California, while it was cleared for a visual approach to the Metropolitan Oakland International Airport, Oakland, California.[62] The NTSB determined that the probable cause of the accident was the pilot's failure to maintain both visual contact with terrain and sufficient altitude for terrain clearance.[63] On October 9, 2000, a FedEx-owned Cessna 208 operated by Empire Airlines collided with wooded terrain in Lummi Island, Washington, during a flight conducted in IMC under a special visual flight rules (SVFR) clearance.[64] The NTSB determined that the probable cause of the accident was the pilot's attempted flight into known adverse weather conditions and the pilot's subsequent failure to maintain altitude above or clearance from the trees.[65]

[62] The report for this accident, NTSB case number LAX95FA076, is available online at <http://www.ntsb.gov/aviationquery/index.aspx>.

[63] Contributing to the accident were the pilot's decision to initiate a descent 14 miles from the airport and the weather, specifically the cloud conditions and darkness.

[64] The FAA defines SVFR conditions as meteorological conditions that are less than those required for basic visual flight rules flight in controlled airspace. SVFR operations must be requested by the pilot and approved by ATC. According to the accident report, the accident flight's leg could not be conducted under IFR because there was no published instrument approach procedure at the destination airport in Eastsound, Washington. The report for this accident, NTSB case number SEA01FA001, is available online at <http://www.ntsb.gov/aviationquery/index.aspx>.

[65] Contributing to the accident were the low ceilings, fog, the pilot's low-altitude flight, rising terrain, and trees.

1.18 Additional Information

1.18.1 Postaccident Safety Action

1.18.1.1 Federal Aviation Administration

Safety Alert for Operators: In-Flight Icing Operations and Training

On March 16, 2010, the FAA issued Safety Alert for Operators (SAFO) 10006, “In-Flight Icing Operations and Training Recommendations,” to encourage all operators to review and amend, if necessary, their flight crewmember and dispatcher training programs to ensure that their programs address SLD icing conditions. The SAFO notes that SLD conditions, which the FAA considers synonymous with freezing drizzle and freezing rain aloft, are “icing conditions containing droplets larger than those required to be demonstrated in aircraft icing certification criteria. SLD may result in ice formation beyond the capabilities of the airplane’s ice protection system to provide adequate ice protection.”

The SAFO referenced the NTSB’s investigation of the October 31, 1994, accident involving an ATR 72-212 that crashed following an in-flight encounter with icing in Roselawn, Indiana.[66] In the SAFO, the FAA recommended that the directors of safety and directors of operations for 14 CFR Part 121 and 135 operators and the training managers for all operators ensure that their training programs include a review of the following: meteorological conditions likely to cause SLD conditions; identification of weather information sources (such as AIRMET, significant meteorological information [SIGMET], center weather advisories, hazardous in-flight weather advisory service, current icing potential, and forecast icing potential) and their use as it relates to flight crewmembers’ and dispatchers’ preflight planning and in-flight decision making; discussion of company and ATC procedures for pilot reports on severe icing; discussion of flight crewmembers’ identification of severe icing conditions associated with freezing rain and freezing drizzle, including immediate exit procedures and ATC procedures should severe icing be encountered; and a review of the FAA publication, “Roll Upset in Severe Icing.”[67]

Proposed Rulemaking for Airplane Certification Requirements for Flight in Icing Conditions

On June 29, 2010, in response to several NTSB safety recommendations (several of which were issued during the NTSB’s investigation of the October 31, 1994, accident in Roselawn, Indiana,[68] and many of which superseded or expanded upon previous safety recommendations issued in 1981),[69] the FAA issued a notice of proposed rulemaking (NPRM),

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[66] See *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 1: Safety Board Report (Revision 9/13/02)*, Aircraft Accident Report NTSB/AAR-96/01 (Washington, DC: National Transportation Safety Board, 1996). <http://www.ntsb.gov/publictn/1996/AAR9601.pdf>.

[67] “Roll Upset in Severe Icing,” *Flight Safety Digest* (January 1996). Information obtained from the Flight Safety Foundation’s website <http://flightsafety.org/fsd/fsd_jan96.pdf> (accessed March 21, 2011).

[68] NTSB/AAR-96/01.

[69] The NTSB first identified the need for the FAA to review and revise the icing criteria in 14 CFR Part 25, Appendix C, in a 1981 safety report. For more information, see *Aircraft Icing Avoidance and Protection, September 9, 1981*, Safety Report NTSB/SR-81/01 (Washington, DC: National Transportation Safety Board, 1981).

"Airplane and Engine Certification Requirements in Supercooled Large Drop, Mixed Phase, and Ice Crystal Icing Conditions," intended to improve the safety of transport-category airplanes operating in SLD, mixed-phase, and ice-crystal icing conditions.[70] Included in the NPRM were proposals for expanding the certification icing environment for transport-category airplanes to include freezing rain and freezing drizzle and to require airplanes most affected by SLD icing conditions to meet certain safety standards in the expanded certification icing environment, including additional airplane performance and handling requirements. The NPRM noted that freezing drizzle is outside the icing envelope[71] currently specified in 14 CFR Part 25, Appendix C, which contains the certification requirements for transport-category airplanes.[72]

1.18.1.2 Empire Airlines

On March 17, 2009, Empire Airlines' Director of Flight Operations wrote an email to NTSB investigators detailing the company's postaccident actions. These actions included the following:

Training Guidance for Flap Anomalies

Empire Airlines distributed guidance to all check airmen and the FlightSafety ATR program manager that stated the following:

> In the course of conducting flight training or checking in the ATR (airplane or simulator) and specifically while executing flap malfunction and reduced flap landing, do not let the crew think that you want them to continue the approach without taking the time to complete the QRH procedure(s), reset the speed bugs, rebrief the approach, etc…Depending on where the crew recognizes the flap problem, they should probably ask ATC (instructor/check airman) for a delay vector or hold while they complete the QRH before continuing the approach. The point is we don't want to train or check differently than we want the crew to fly the aircraft. We should expect them to delay the approach until all the QRH procedures and briefs are complete.

Flight Information Bulletin for Airspeed Bugs

On February 23, 2009, Empire Airlines issued Flight Information Bulletin 09-01 to all ATR crewmembers explaining the proper determination and setting of airspeed bugs for flight in icing conditions. The company also added expanded procedures to the ATR pilot handbook for flight crews to be aware of errors in setting airspeed bugs and added a procedure for the setting and readback of the bugs during the departure and approach briefings.

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[70] 75 *Federal Register* (FR) 37311-37339 (June 29, 2010).

[71] According to the NPRM, the term "icing envelope" refers to "the environmental icing conditions within which the airplane must be shown to be able to safely operate."

[72] For information about the NTSB's August 27, 2010, comments to the FAA regarding the NPRM, see section 2.4.1.2.

Flight Operations Bulletin for Icing

On February 27, 2009, Empire Airlines issued Flight Operations Bulletin 09-04, which contained information to supersede the information contained in the GOM, section 8-9, "Icing." The flight operations bulletin, which was intended for both ATR flight crews and flight followers, included the following information:

> Freezing rain…and freezing drizzle…are not covered by the certification icing envelope as defined in Part 25, Appendix C. Takeoff or landing operations in known or reported [freezing rain or freezing drizzle] of any intensity, are prohibited.

Special Emphasis Icing Training

Empire Airlines implemented special emphasis icing training, which increased the time spent during ground training for all ATR pilots and dispatchers and included a review of the ATR *Cold Weather Operations* publication,[73] the NASA *Tailplane Icing* video, and the 14 CFR Part 25, Appendix C, icing certification envelope. The training also included a review of SLD; severe icing; icing reports, forecasts, advisories, AIRMETs, and SIGMETs; and a review of aircraft performance and the recommended maximum crosswind and tailwind components with respect to operations with contaminated runways.

1.18.1.3 FedEx Feeder Operations

In April 2009, FedEx facilitated a safety summit with its feeder operators to address the circumstances of this accident and facilitate training improvement and adherence to best practices. As a result of the safety summit, the ATR training curriculum taught at FlightSafety was modified to include stick-shaker and stick-pusher recognition and recovery training, special purpose operational training, and line-oriented flight training (one module of which is still under development). ATR initial training was also increased with two sessions added. In addition, company instructors were placed on site at FlightSafety to perform company-specific training and check rides to complement FlightSafety's instruction.

All FedEx feeder operators developed "no-go" weather items (similar to those contained in Empire Airlines' Flight Operations Bulletin 09-04) that prohibit takeoff or landing operations in known or reported freezing rain or freezing drizzle. All of the operators have implemented procedures for ensuring that airspeed bugs are properly used and verified during all phases of flight. Ice evidence probes (IEPs) have been installed on all ATR airplanes that were not so equipped (the installations were completed by October 2009).

[73] *Cold Weather Operations: Be Prepared for Icing* (2008).

1.18.2 Previously Issued Safety Recommendations

1.18.2.1 Flight Crew Monitoring and Workload Management Skills for Single and Multiple Abnormal Situations

On February 23, 2010, as a result of its investigation of the February 12, 2009, accident involving a Colgan Air (operating as Continental Connection) Bombardier DHC-8-400, which crashed during an instrument approach in Buffalo, New York,[74] the NTSB issued Safety Recommendation A-10-10, which asked the FAA to do the following:

> Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to review their standard operating procedures to verify that they are consistent with the flight crew monitoring techniques described in Advisory Circular (AC) 120-71A, "Standard Operating Procedures for Flight Deck Crewmembers"; if the procedures are found not to be consistent, revise the procedures according to the AC guidance to promote effective monitoring.

On June 22, 2010, the FAA responded that it was considering options such as issuance of a SAFO or an information for operators (InFO) bulletin to address this recommendation. On January 25, 2011, the NTSB indicated that although such action may represent part of an acceptable response to this recommendation, the FAA must also ensure that the guidance provided in documents like SAFOs is implemented.[75] Pending the recommended actions, the NTSB classified Safety Recommendation A-10-10 "Open—Acceptable Response."

As a result of its investigation of the February 16, 2005, accident involving a Cessna Citation 560 that crashed during an ILS approach in icing conditions,[76] the NTSB issued Safety Recommendation A-07-13, which asked the FAA to do the following:

> 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.

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[74] In this accident, "the flight crew's failure to monitor airspeed" was a contributing factor. See *Loss of Control on Approach, Colgan Air, Inc., Operating as Continental Connection Flight 3407, Bombardier DHC-8-400, N200WQ, Clarence Center, New York, February 12, 2009*, Aircraft Accident Report NTSB/AAR-10/01 (Washington, DC: National Transportation Safety Board, 2010). <http://www.ntsb.gov/publictn/2010/AAR1001.pdf>.

[75] At the same time Safety Recommendation A-10-10 was issued, the NTSB also issued Safety Recommendation A-10-31, which concerns the need to ensure that guidance provided in documents like SAFOs has been implemented. Safety Recommendation A-10-31 asked the FAA to do the following: "Implement a process to document that all 14 *Code of Federal Regulations* Part 121, 135, and 91K operators have taken appropriate action in response to safety-critical information transmitted through the safety alert for operators process or another method." On January 25, 2011, the NTSB classified this recommendation "Open—Acceptable Response," pending FAA action.

[76] The NTSB determined that the probable cause of the accident included "the flight crew's failure to effectively monitor and maintain airspeed." See *Crash During Approach to Landing, Circuit City Stores, Inc., Cessna Citation 560, N500AT, Pueblo, Colorado, February 16, 2005*, Aircraft Accident Report NTSB/AAR-07/02 (Washington, DC: National Transportation Safety Board, 2007). <http://www.ntsb.gov/ntsb/publictn/2007/AAR0702.pdf>.

On May 17, 2007, the FAA stated that monitoring skills and workload management are part of CRM and that current CRM regulations adequately address the issues in this recommendation. However, the FAA indicated that it would consider identifying in its work program a list of required inspections, reemphasizing to the regional and FSDO managers the need to validate the training that is already required and verify its effectiveness. On September 9, 2008, the NTSB responded that the FAA's list should include a strong emphasis on monitoring and workload management components of the CRM program. On February 23, 2010, as a result of the FAA's lack of progress in response to the safety recommendation and the NTSB's subsequent investigation of the Colgan Air accident,[77] the NTSB reiterated A-07-13 and classified it "Open—Unacceptable Response."

On May 19, 2009, as a result of the NTSB's investigation of the September 28, 2007, accident involving American Airlines flight 1400, a McDonnell Douglas DC-9-82, which experienced an in-flight engine fire and nose landing gear anomaly that presented the flight crew with multiple, simultaneous emergency and abnormal situations,[78] the NTSB issued Safety Recommendations A-09-24 and -25, which asked the FAA to do the following:

> Establish best practices for conducting both single and multiple emergency and abnormal situations training. (A-09-24)
>
> Once the best practices for both single and multiple emergency and abnormal situations training asked for in Safety Recommendation A-09-24 have been established, require that these best practices be incorporated into all operators' approved training programs. (A-09-25)

On August 11, 2009, the FAA responded that it supports "realistic, scenario-based training that serves to develop pilot psychomotor skills as well as critical thinking and decision-making abilities in response to the range of unusual or unanticipated events that may occur during flight operations." The FAA stated that, on January 12, 2009, it published an NPRM, "Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers,"[79] that included such scenario-based training for all 14 CFR Part 121 operators. The FAA also indicated that it planned to revise FAA Order 8900.1, "Flight Standards Information Management System," to require POIs to withdraw approval of any Part 121 training program that does not include such training.

On April 2, 2010, the NTSB responded that, although issuance of the final rule proposed in the NPRM would give the FAA the regulatory framework to require the training, the NTSB remained concerned that, without a guide to best practices, inspectors and operators would have difficulty creating effective programs. Pending the outcome of the FAA's planned review of regulatory and policy framework to determine whether additional guidance or requirements are

[77] NTSB/AAR-10/01.

[78] See *In-Flight Left Engine Fire, American Airlines Flight 1400, McDonnell Douglas DC-9-82, N454AA, St. Louis, Missouri, September 28, 2007*, Aircraft Accident Report NTSB/AAR-09/03 (Washington, DC: National Transportation Safety Board, 2009). <http://www.ntsb.gov/publictn/2009/AAR0903.pdf>.

[79] 74 FR 1280 (January 12, 2009).

necessary, the NTSB classified Safety Recommendations A-09-24 and -25 “Open—Acceptable Response.”

1.18.2.2 Go-Around Callout

During the NTSB’s investigation of the February 18, 2007, accident involving a Shuttle America (doing business as Delta Connection) Embraer ERJ-170, which overran the runway during landing,[80] the NTSB concluded that both the PF and the PM should have the authority to call for a go-around maneuver because one pilot might detect a potentially unsafe condition of which the other pilot is unaware. As a result, the NTSB issued Safety Recommendation A-08-18, which asked the FAA to do the following:

> Require 14 *Code of Federal Regulations* Part 121, 135, and Part 91 subpart K operators to have a written policy emphasizing that either pilot can make a go-around callout and that the response to the callout is an immediate missed approach.

On September 26, 2008, the FAA responded that it would publish a SAFO that discusses the hazards associated with cockpit crewmembers who do not immediately and instinctively react to a go-around callout while on an approach for landing. The FAA also stated that it would revise FAA Order 8900.1 to include guidance to POIs to have all 14 CFR Part 121, 135, and 91 subpart K operators develop written policy that indicates that either pilot can make a go-around callout and that the response to the callout is an immediate missed approach.

On June 22, 2009, the NTSB indicated that, pending the FAA’s revision of FAA Order 8900.1 and its completion of a survey to ensure that all operators have developed and implemented the recommended policy, Safety Recommendation A-08-18 was classified “Open—Acceptable Response.” On March 1, 2010, the FAA issued SAFO 10005, “Go-Around Callout and Immediate Response,” which provided information to operators and recommended that they provide written policy to flight crews regarding go-around callouts. The other requested action items have not yet been completed.

1.18.2.3 Low-Airspeed Alerting Systems

As a result of the February 12, 2009, Colgan Air accident,[81] the NTSB issued Safety Recommendation A-10-12, which superseded Safety Recommendations A-03-53 and -54[82] and asked the FAA to do the following:

[80] See *Runway Overrun During Landing, Shuttle America, Inc., Doing Business as Delta Connection Flight 6448, Embraer ERJ-170, N862RW, Cleveland, Ohio, February 18, 2007,* Aircraft Accident Report NTSB/AAR-08/01 (Washington, DC: National Transportation Safety Board, 2008). <http://www.ntsb.gov/publictn/2008/AAR0801.pdf>.

[81] NTSB/AAR-10/01.

[82] Safety Recommendations A-03-53 and -54, which were issued on December 2, 2003, were classified “Closed—Unacceptable Action/Superseded” on February 23, 2010, because of a lack of progress. Safety Recommendation A-03-53 asked the FAA to do the following: “Convene a panel of aircraft design, aviation operations, and aviation human factors specialists, including representatives from the National Aeronautics and

> For all airplanes engaged in commercial operations under 14 *Code of Federal Regulations* Parts 121, 135, and [Part 91 subpart] K, require the installation of low-airspeed alert systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-speed condition.

On June 22, 2010, the FAA responded that it planned to task the Aviation Rulemaking Advisory Committee (ARAC) with developing recommendations for potential requirements to address low-airspeed alerting systems. On January 25, 2011, the NTSB acknowledged that asking the ARAC to address the issue of low-airspeed alerting systems may represent the first step in an acceptable response to this recommendation. However, due to the FAA's lack of progress in this area, the NTSB classified Safety Recommendation A-10-12 "Open—Unacceptable Response," pending substantive action by the ARAC to address this recommendation.

1.18.2.4 First Officer Assertiveness

As a result of its investigation of the February 19, 1996, accident involving Continental Airlines flight 1943, a Douglas DC-9-32, which landed wheels up,[83] the NTSB issued Safety Recommendations A-97-05 and -06, which asked the FAA to do the following:

> Require all principal operations inspectors of 14 CFR Part 121 carriers to ensure that the carriers establish a policy and make it clear to their pilots that there will be no negative repercussions for appropriate questioning in accordance with crew resource management techniques of another pilot's decision or action. (A-97-05)

> Require all principal operations inspectors of 14 CFR Part 121 carriers to ensure that crew resource management programs provide pilots with training in recognizing the need for, and practice in presenting, clear and unambiguous communications of flight-related concerns. (A-97-06)

On October 30, 1998, the FAA issued AC 120-51C (currently AC 120-51E), which emphasized the importance of all levels of management to support a safety culture that promotes communication by encouraging appropriate questioning and that there will be no negative repercussions for appropriate questioning of one pilot's decision or action by another. The NTSB also requested that the FAA issue a flight standards information bulletin (FSIB) to provide guidance to POIs to ensure that operators are complying with the information presented in

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Space Administration, to determine whether a requirement for the installation of low-airspeed alert systems in airplanes engaged in commercial operations under 14 *Code of Federal Regulations* Parts 121 and 135 would be feasible, and submit a report of the panel's findings." Safety Recommendation A-03-54 asked the FAA to do the following: "If the panel requested in Safety Recommendation A-03-53 determines that a requirement for the installation of low-airspeed alert systems in airplanes engaged in commercial operations under 14 Code of Federal Regulations Parts 121 and 135 is feasible, establish requirements for low-airspeed alert systems, based on the findings of this panel."

[83] In this accident, the captain rejected, without any discussion, the first officer's go-around request, and the first officer failed to challenge his decision. See *Wheels-Up Landing, Continental Airlines Flight 1943, Douglas DC-9-32, N10556, Houston, Texas, February 19, 1996,* Aircraft Accident Report NTSB/AAR-97/01 (Washington, DC: National Transportation Safety Board, 1997). <http://www.ntsb.gov/publictn/1997/AAR9701.pdf>.

AC 120-51C. Based on the lack of action by the FAA to issue the FSIB, on February 23, 2000, the NTSB classified these recommendations "Closed—Unacceptable Action."

1.18.3 Airplane Equipment Options

1.18.3.1 Aircraft Performance Monitoring System

Since November 2005, new production ATR 42 and ATR 72 airplanes have been equipped with an aircraft performance monitoring (APM) system[84] designed to assist flight crews with monitoring airplane performance during operations in icing conditions. According to ATR's *Cold Weather Operations* publication,[85] ATR developed the APM to enhance a flight crew's ability to detect severe icing conditions after finding that flight crews do not always adequately monitor the cues and follow the procedures established for responding to severe icing encounters. The APM uses FDR-recorded parameters and other information[86] to calculate and compare the airplane's actual performance (with respect to airspeed and drag) with its expected performance. The APM also computes the actual minimum icing and severe icing airspeeds. The APM function is included in the airplane's multipurpose computer and requires no additional sensors or any calculation of atmospheric ice content.

If the APM detects that the minimum airspeed requirements are not being met or that degraded airplane performance is present, the APM alerts the flight crew via aural chimes and annunciator lights on each pilot's panel. The system is designed to provide these alerts only when the static air temperature is below 10° C, the airplane's flaps and landing gear are retracted, both engines are operating, and level 2 or 3 icing protection is engaged or an icing signal is provided by the ice detector.

During cruise flight, if the APM detects that the airplane's indicated airspeed is 10 kts lower than the expected value, the blue "CRUISE SPEED LOW" annunciator lights will illuminate to alert the flight crew to monitor the icing conditions and airspeed.[87] During climb, cruise, or descent, if the APM detects that the airplane's performance is becoming degraded, the amber "DEGRADED PERF" annunciator lights will illuminate with a single aural chime to alert the flight crew to apply the appropriate QRH procedures to verify that the deicing protection is on, maintain red-bug airspeed plus 10 kts, and check for severe icing cues or abnormal handling. The QRH states that, if such cues are absent, the flight may be continued and that icing conditions and airspeed should be monitored. If the APM detects that the airspeed decays further and the minimum icing airspeed is reached, the amber "INCREASE SPEED" annunciator lights will flash with a single aural chime to alert the flight crew to increase the airspeed.

According to ATR, had the accident airplane been equipped with an APM, the flight crew would have received the blue "CRUISE SPEED LOW" annunciator lights after about 10 minutes

[84] The modification began with ATR 42-500 SN 641 and ATR 72-212A SN 726. The accident airplane, which was older, was not equipped with an APM.

[85] *Cold Weather Operations: Be Prepared for Icing* (2008).

[86] The APM also uses aircraft weight information that must be input by the flight crew.

[87] The light will extinguish once the appropriate airspeed is maintained.

of cruise flight in the icing conditions at FL 180. During the descent through about 5,000 feet msl, the flight crew would have received the blue "CRUISE SPEED LOW" annunciator lights about 70 seconds before they selected the flap extension and the amber "DEGRADED PERF" annunciator lights and single chime about 40 seconds before they selected the flap extension. After the flight crew selected the flap extension, an APM would have provided no further annunciator lights or chimes because the system requires a flaps-up configuration.

After the APM system was first introduced, on October 12, 2005, the Direction Générale de l'Aviation Civile (DGAC) of France issued Recommendation Bulletin 2005/31(B) to "inform the concerned authorities and operators of the new design improvement" and to "strongly recommend" that ATR operators install the APM on their ATR fleets; the FAA did not issue a similar advisory. In the bulletin, DGAC indicated that "no unsafe condition exists" for airplanes that are not equipped with an APM provided that the flight crew applies the appropriate procedures for detecting and responding to a severe icing encounter. However, DGAC noted that an APM can help flight crewmembers recognize when they enter severe icing conditions and can help them respond appropriately to such an encounter. On December 11, 2006, ATR issued All Operators Message 42-72/2006/08 to notify all operators of the availability of the APM retrofits and to recommend their installation. ATR also provided operators with information about the APM in various publications and at several flight operations conferences worldwide.

On August 10, 2009, the European Aviation Safety Agency (EASA) issued AD 2009-0170, effective August 24, 2009, that required all EASA-participating operators (operators in the European Community, its Member States, and the European third countries) of ATR 42 and 72 airplanes not originally equipped with the APM system to retrofit their airplanes with the system within 72 months or by the second "C" check,[88] whichever occurs first. The FAA took no similar action. As a result, APM system retrofits are optional for U.S. operators of ATR 42 and ATR 72 airplanes not originally equipped with the system. According to ATR, of the 780 ATR 42 and ATR 72 airplanes in service worldwide, 250 are equipped with APMs. Of the 90 ATR 42 and ATR 72 airplanes in the United States, none are equipped with APMs.

1.18.3.2 Flap Malfunction or Asymmetry Light

Several ATR airplanes, including all ATR 42-200, -300, and -320 models (like the accident airplane), were certificated without a cockpit light for a flap asymmetry or malfunction. The certification basis that applies to these airplanes includes 14 CFR 25.699,[89] which states the following:

> there must be a means to indicate to the pilots the position of each lift or drag device having a separate control in the cockpit to adjust its position. In addition, an indication of unsymmetrical operation or other malfunction…must be provided

[88] A "C" check is a heavy maintenance inspection performed at intervals based on manufacturer-specified airplane usage parameters.

[89] According to EASA, the original certification basis for the ATR 42-320 was *Joint Aviation Requirements*, change 8 for paragraph 25.699, which is similar in content to 14 CFR 25.699, amendment level 25-23, effective May 8, 1970.

> when such indication is necessary to enable pilots to prevent or counteract an unsafe flight…condition.

Certification testing demonstrated that a flap asymmetry in these airplanes (which is limited to less than 10° by the airplanes' flap asymmetry detection system)[90] did not constitute an unsafe flight condition because the airplanes remained controllable. Later-model ATR airplanes, including all ATR 42-400 and -500 and all ATR 72-101, -102, -201, -211, -212, and -212A models, have a cockpit light that indicates a flap asymmetry. The airplane manufacturer stated that the asymmetry light was added as part of an upgrade to the airplanes' flight management system. The flap asymmetry light was designed to illuminate amber any time that an asymmetry greater than 6.7° occurred. Nearly all transport-category airplanes, with the exception of the ATR 42-200, -300, and -320 models and the Cessna 500, 550, 553, 560, and 560XL models, are certificated with some type of flap malfunction indicator in the cockpit, some of which specifically indicate flap asymmetry.

1.18.3.3 Ice Evidence Probe

Since 1995, new-production ATR airplanes have been equipped with an IEP, which is mounted so that it is visible from the left-side cockpit window and is considered the primary means for flight crews to monitor ice accumulation.[91] The IEP provides an airfoil-shaped surface upon which ice accumulation can be visually detected and is designed to retain ice on its surface until the entire aircraft is free of ice, thus helping flight crews determine when critical surfaces of the airplane may be free of ice. The IEP is automatically illuminated for use during night operations when the airplane's navigation lights are turned on. For all ATR airplanes that were not originally equipped with IEPs, ATR provided the operators with the service bulletin and kits necessary for installing IEPs free of charge. These kits were distributed in 1995, and the installation was optional. The accident airplane was not equipped with an IEP.

[90] FAA personnel indicated that most airplanes' flap asymmetry detection systems are similar in that they limit the amount of asymmetry that can occur.

[91] *Cold Weather Operations: Be Prepared for Icing* (2008).

2. Analysis

2.1 General

The captain and the first officer were certificated in accordance with Federal regulations and were current and qualified in accordance with Empire Airlines' training requirements. The investigation found no evidence that the pilots' performance was affected by any behavioral or medical condition, or by the use of alcohol or drugs.

The airplane was loaded within weight and CG limits and was maintained in accordance with 14 CFR Part 121. Although Empire Airlines could not immediately locate the left engine's AD records, work orders and other records were located that indicated the AD compliance items had been performed. The investigation found no evidence that indicated any mechanical anomaly with the engines, and FDR data indicated that the engines' performance was consistent with normal operations.

The flight experienced two separate periods of airframe ice accretion, the first during cruise flight at FL 180 and the second during descent below 6,000 feet msl. The flight crew selected ice protection during both icing encounters, and no evidence indicated any mechanical anomalies with the airplane's deicing and anti-icing systems. According to the captain, following the first icing encounter, during the descent above 6,000 feet msl, "substantial amounts of ice" came off the airplane. The shedding of ice is consistent with the presence of a layer of air with temperatures above freezing between 6,000 and 11,000 feet msl due to a temperature inversion. Further, performance calculations based on FDR data indicated that, during the descent between 14,000 to about 5,000 feet msl, the airplane's performance was as expected for an ice-free airframe. During the approach into LBB, the airplane began to accumulate ice again when it descended into moderate icing conditions resulting from light freezing drizzle, a weather condition that was outside its icing certification envelope as specified in 14 CFR Part 25, Appendix C.[92]

During the approach as the airplane descended through about 4,800 feet msl, the FDR recorded that a flap asymmetry occurred about 1 second after the cockpit flap position lever was positioned to command 15° flaps. The FDR recorded no operational anomalies with the airplane's hydraulic systems, and the flight crew reported none. Performance data indicated that, when the flight crew commanded 15° flaps, a flap asymmetry occurred with the left flaps extending 8° to 10° and the right flaps not extending. The data further indicated that the flaps returned to a symmetric state (about 4.5°) about 25 seconds before ground impact.

Based on the circumstances of the accident flight, a number of scenarios could have resulted in a flap asymmetry, and the investigation evaluated the possibility that a mechanical anomaly, flap actuator jamming, mechanical restriction of the movement of the right flaps, or hydraulic fluid contamination may have occurred. Postaccident impact and fire damage to the right flaps limited the extent to which preimpact system integrity could be determined

[92] For information about the NTSB's longstanding concerns about the operation of airplanes in weather conditions that are outside their icing certification envelope, see section 2.4.1.

(components from the left flaps sustained less damage during the accident sequence and the left flaps' actuators functioned when tested). X-ray examinations and disassembly of all four flap actuators (for both the left and right flaps) showed that their internal components were intact at the time that the asymmetry occurred, that hydraulic fluid (or evidence of hydraulic fluid) was present in each actuator, and that no evidence existed of any mechanical anomaly or jamming of the actuators. Examination of the available components from the right flaps revealed no evidence that any mechanical restriction of the movement of the flaps had occurred with respect to those components (thermal damage precluded examination of the entire system).

According to ATR, ice formation on the flap surfaces could not result in a delayed extension of the flaps because in all types of icing conditions, runback icing does not exceed 15 to 20 percent of the wing chord on the upper wing surface and 30 to 40 percent of the wing chord on the lower wing surface and that these limits are upstream of the flaps. Further, ATR noted that there were no reports of a flap asymmetry due to ice formation in the operational history of the aircraft make/model. However, because the airplane was operating outside of its icing certification envelope at the time of the accident and runback ice was found on the lower surface of a separated section of the right aileron, the investigation could not rule out the possibility that ice could have formed and either delayed or restricted the flap extension and resulted in a flap asymmetry.

Testing of recovered hydraulic fluid found that solid particles, which testing found to be consistent with heated hydraulic fluid, were found in the hydraulic fluid lines and the connector port for the right outboard flap actuator. No similar particles were found in any fluid samples from the airplane's hydraulic reservoir or from the examined hydraulic system filters. Therefore, the identified solid particles appeared to have changed state only after exposure to the high temperatures of the postimpact fire.

The investigation considered that the right inboard flap actuator (installed as original equipment on the airplane) may have sustained interior damage during the airplane's 1998 right engine fire event that may have gone undetected and resulted in a malfunction of the actuator. The investigation also considered that hydraulic fluid contamination (such as from foreign particles or air) could result in a flap actuation delay. No evidence of any preexisting condition was discovered. However, because of the extent of the impact and postcrash fire damage to the right flaps' actuators and the hydraulic system components, the investigation could not determine if any evidence of either condition may have been present before the accident. The NTSB concludes that, because of the extent of the impact and postaccident fire damage to the right flaps and flap actuators, the reason for the airplane's flap asymmetry could not be determined.

The following analysis describes the accident sequence and examines the safety issues associated with the flight crew's performance during the approach in response to the flap anomaly, the dispatch of the flight into freezing drizzle conditions, the communication of flight crew and HAZMAT information to the emergency response personnel, airplane equipment considerations, and simulator-based training for pilots who fly in icing conditions.

2.2 Accident Sequence

During the accident approach, at 0434:24, the first officer was flying using the autopilot and called for a flap setting of 15°, which is the appropriate approach flap setting for the ATR 42; however, a flap asymmetry occurred. During a postaccident interview, the first officer stated that she noticed that the airplane did not decelerate as expected (and briefly accelerated); however, she did not say anything to the captain about her observation. The airplane's failure to decelerate is consistent with a flap asymmetry because the abnormal condition provided less lift and drag than the desired 15° approach flap configuration. Further, the presence of airframe ice accretion also affected the drag forces on the airplane. As a result, the engine power settings that would have been appropriate during a typical approach (with 15° flaps and no ice contamination) would not have applied to the accident approach. However, the FDR showed that at 0434:54, about 30 seconds after the asymmetry occurred, the first officer reduced engine power to about 3 percent torque, which was likely an effort to reduce the airspeed; as the airplane continued its descent on autopilot, only a minimal increase in engine power was commanded.

About 40 seconds after the asymmetry occurred, the captain observed a problem with the flaps; at this time, the airplane was just outside the LOM/FAF at an altitude of about 1,400 feet agl. In response, the captain began a nonstandard procedure to troubleshoot the flap problem and did not verbalize his plan of action with the first officer, who continued flying the approach. The airplane's airspeed decreased throughout the approach, resulting in an increasing AOA, and the stick shaker activated when the airplane was about 900 feet agl at an airspeed of 125 kts. The airplane performance study found that the stick shaker activated at the setting prescribed for flight in icing conditions.[93]

The stick shaker disconnected the autopilot at 0435:29, and the first officer began to manually fly the approach, increasing engine power to about 70 percent torque. Control force estimates showed that the first officer was applying about 35 to 40 lbs of rudder pedal pressure and about 13 lbs of control wheel force to manually counter the flap asymmetry. However, under manual control, the airplane deviated high and to the right of the runway 17R ILS glidepath, indicating that the first officer may not have immediately recognized the extent of the airplane's right banking tendency induced by the flap asymmetry. As the deviation increased, at 0435:40, the first officer asked the captain, "should I go around?" The captain replied, "no" and instructed the first officer to "keep descending." About 4 seconds later, when with a strained voice the first officer stated, "we're getting close here," the captain asked the first officer if she wanted him to take the controls, and she replied that she did.

After the accident, the captain stated that he had not heard the autopilot disconnect alert and was surprised to see that the first officer was manually flying the airplane. No autopilot disconnect alert was heard on the CVR. Postaccident testing of the autopilot disconnect alerting system revealed no malfunctions. On the ATR 42-320, the aural stall warning has priority over the autopilot disconnect aural alert. By the time that the autopilot disconnect aural alert would have sounded (about 1.1 seconds after the aural stall warning), the first officer likely responded

[93] For more information about the captain's actions and the flight crew's training and procedures for responding to flap anomalies and the stick shaker, see section 2.3.1.

to the stall warning by pushing the autopilot disconnect push button, which silenced the pending autopilot disconnect alert.

When the captain took control, the airplane was about 700 feet agl at 143 KIAS, high and to the right of the approach course. At 0436:00, about 10 seconds after the captain took control, the forces exerted on the cockpit controls peaked with maximum forces on the control column, control wheel, and rudder pedals of 36 lbs, 29 lbs, and 112 lbs, respectively.[94] When these peak forces were applied, the airplane was descending through about 500 feet agl (the reported ceiling) and likely emerged from the clouds, allowing the captain to establish visual contact with the runway. At this time, the airplane was more than 300 feet right of the localizer course, and the captain's control inputs were consistent with a course correction to align the airplane with the runway. About 2 seconds later, the flaps returned to a symmetric state, and control input to counteract the flap asymmetry was no longer required.

Immediately after the captain exerted the peak forces on the cockpit controls, about 27 seconds before impact, the aural stall warning and the stick shaker activated for the second time, concurrent with the TAWS warning, "pull up. pull up." Procedures for responding to either the stick shaker or the TAWS warning require the immediate application of maximum engine power; however, 2 seconds later, the captain reduced the airplane's engine power to about 10 percent torque, and he did not call for maximum engine power until 15 seconds later at 0436:17. As the captain continued the approach, the airspeed again decreased below the minimum safe approach speed.

At 0436:18, about 9 seconds before impact, the pilot began to pull back on the control column for several seconds. In response to the pilot's pull on the control column, the pitch attitude, AOA, and load factor all began increasing. At 0436:19, the aural stall warning and the stick shaker activated for the third time. The airspeed when the stall warning occurred was about 124 kts, approximately 19 kts below the minimum safe airspeed for the approach of 143 kts. About 2 seconds after the stall warning occurred, the airplane experienced an uncommanded roll followed by a series of roll, yaw, and pitch oscillations, which continued until ground impact.

No evidence existed of airplane performance behavior consistent with an aerodynamic stall or with a loss of lateral control until after 0436:20. Further, no evidence existed of a sudden change in aileron hinge movement throughout the approach. The airplane performance study and simulations determined that the performance degradation due to ice accretion never exceeded the airplane's thrust performance, nor would it have exceeded the airplane's flight control capabilities if the minimum safe airspeed had been maintained. Therefore, the NTSB concludes that the airplane was controllable with the flap asymmetry and airframe ice contamination and could have been maneuvered and landed safely if the minimum safe airspeed had been maintained.

If the captain had responded appropriately to the concurrent stall and TAWS warnings that occurred 27 seconds before impact by immediately initiating a go-around maneuver when the airplane was at an altitude of about 500 feet agl, he likely would have been able to arrest the

[94] According to 14 CFR 25.143(d), the maximum control forces allowable for short-term application of pitch and roll, when two hands are available, and yaw are 75 lbs, 50 lbs, and 150 lbs, respectively.

airplane's descent, increase its airspeed, and avoid an aerodynamic stall. The NTSB concludes that the captain's failure to immediately respond to the aural stall warning, the stick shaker, and the TAWS warning resulted in his inability to arrest the airplane's descent and avoid impact with the ground.

2.3 Human Performance

Under normal conditions, the approach-to-landing is a high-workload phase of flight for pilots. Required tasks include controlling, maneuvering, and configuring the airplane; performing final landing checks; and evaluating the airplane's performance relative to the landing criteria. Pilots are expected to capture and prioritize critical information, analyze that information, and take appropriate action. Performing these tasks can become increasingly difficult as workload increases beyond routinely experienced levels, and, during the accident approach, both the icing conditions and the flap anomaly combined to increase the flight crew's workload.

Research demonstrates that emergency situations increase workload and require additional effort to manage effectively because of the stress involved, human cognitive limitations, and the lack of opportunity for pilots to practice these skills on a regular basis compared to the skills used in normal operations.[95] The NASA emergency and abnormal situations study,[96] which analyzed the NTSB's findings from its 1994 safety study that reviewed flight crew-involved, major accidents,[97] also noted that, during high-workload conditions, performance deficiencies, including narrowing of attention and impairment of short-term memory, could result from inherent limitations in cognitive processes and the effect of stress on human performance.

Training, experience, and SOPs are developed to mitigate errors, especially during dynamic and high-workload situations. However, after the flight crewmembers recognized that a flap problem existed, they failed to follow their training and did not perform a go-around maneuver and reference the QRH checklist for the flap anomaly procedure; they did not comply with Empire Airlines' procedures (outlined in the GOM) that address abnormal situations. As a result, a compounding situation unfolded in which the flight crew missed several opportunities to apply the correct SOPs to ensure the safety of the flight.

SOPs are universally recognized as basic to safe aviation operations. Well-designed cockpit procedures are an effective countermeasure against operational errors, and disciplined compliance with SOPs, including strict checklist discipline, provides the basis for effective crew coordination and performance. Operational data confirm the importance of strict compliance with SOPs for safe operations. For example, industry data show that pilots who intentionally deviated from SOPs were

[95] R.K. Dismukes, G.E. Young, and R.L. Sumwalt, "Cockpit Interruptions and Distractions: Effective Management Requires a Careful Balancing Act," *ASRS Directline*, vol. 10 (1998), pp 4-9.

[96] B.K. Burian, I. Barshi, and K. Dismukes, *The Challenge of Aviation Emergency and Abnormal Situations*, NASA Technical Memorandum 2005-213462 (Moffett Field, California: National Aeronautics and Space Administration, 2005).

[97] See *A Review of Flight Crew-Involved, Major Accidents of U.S. Air Carriers, 1978 through 1990,* Safety Study NTSB/SS-94/01 (Washington, DC: National Transportation Safety Board, 1994).

three times more likely to commit other types of errors, mismanage errors, and find themselves in undesired situations compared with pilots who did not intentionally deviate from procedures.[98] According to AC 120-71A, in its study of controlled flight into terrain accidents, the Commercial Aviation Safety Team, which included FAA, industry, and union representatives, found that almost 50 percent of the studied accidents related to the flight crew's failure to adhere to SOPs or the certificate holder's failure to establish adequate SOPs. The NTSB has repeatedly cited casual cockpit discipline and inadequate compliance with SOPs as contributing factors to accidents.[99]

2.3.1 Captain's Nonstandard Responses

After the captain stated that the airplane had "no flaps," no further discussion occurred as to what actions should be taken, and no reference was made to the QRH. Instead, the captain retrieved and used a flashlight to check the circuit breakers located behind the first officer's seat while the first officer continued to fly the approach. During postaccident interviews, the captain indicated that he checked the circuit breakers because he felt that he needed to determine what the malfunction was before he could respond with the appropriate checklist. The first officer stated that she was a little concerned about the captain's actions and that she thought that he should have been more focused on the tasks associated with landing the airplane. However, at no time during the flight did she verbalize her concerns.

Both the captain and the first officer had been trained to perform a go-around maneuver and reference the QRH if a flap problem occurred during an approach. Based on the flight crew's training and the low altitude at which they first noticed the flap anomaly, the appropriate response would have been to maintain control of the airplane, perform a go-around manuever (climb the airplane to a safe altitude according to the missed approach procedure), and refer to the QRH procedure for a flap anomaly. If a go-around maneuver had been performed, after climbing to 6,000 feet msl, the airplane would have exited icing conditions and reentered a layer of warmer air with temperatures above freezing. The flight crew could then have completed the QRH procedure and determined whether to attempt another approach into LBB or proceed to the flight's alternate airport, which had no reported precipitation.

Although the captain's observation that the airplane had "no flaps" was inaccurate because the airplane actually had a flap asymmetry, the inaccuracy was irrelevant because the same QRH procedure applied for both a no-flaps condition and a flap asymmetry. The pilots were trained to verify the flap conditions by looking in the cockpit at the flap position indicator and out the side windows at the flap position fairings. The procedure would then have been to

[98] The data came from the LOSA Collaborative, which is a network of researchers, safety professionals, pilots, and airline representatives collaborating to provide, among other things, oversight and implementation of line operational safety audits and a forum of information exchange regarding these audits. More information is available online at <http://losacollaborative.org/>.

[99] For more information, see (a) *Collision with Trees and Crash Short of the Runway, Corporate Airlines Flight 5966, BAE Systems BAE-J3201, N875JX, Kirksville, Missouri, October 19, 2004,* Aircraft Accident Report NTSB/AAR-06/01 (Washington, DC: National Transportation Safety Board, 2006); (b) *Attempted Takeoff From Wrong Runway, Comair Flight 5191, Bombardier CL-600-2B19, N431CA, Lexington, Kentucky, August 27, 2006,* Aircraft Accident Report NTSB/AAR-07/05 (Washington, DC: National Transportation Safety Board, 2007); and (c) *Crash of Pinnacle Airlines Flight 3701, Bombardier CL-600-2B19, N8396A, Jefferson City, Missouri, October 14, 2004,* Aircraft Accident Report NTSB/AAR-07/01 (Washington, DC: National Transportation Safety Board, 2007).

place the cockpit flap control lever in the position nearest to the actual position of the flaps and next perform a reduced-flaps landing procedure (in this case, a no-flaps landing). The no-flaps landing procedure included briefing the no-flaps approach procedure and resetting the airspeed bugs.

The NTSB acknowledges that recognizing the cockpit warning indicators, identifying the nature of any problems, and choosing a response procedure requires considerable attention. As noted beneath the QRH Table of Contents, before a flight crew performs a procedure, the flight crew "must assess the situation as a whole, taking into consideration the failures, when fully identified, and the flight constraints imposed." According to the GOM, in the event of an inoperative or malfunctioning flight control system, if the airplane is controllable, the flight crew "should complete only the applicable checklist procedures" and "not attempt any corrective action beyond those specified."

Although the NTSB recognizes that the PIC has authority to deviate from prescribed procedures in the interest of safety, no indication existed that the captain considered this to be an emergency condition, and the airplane was controllable. Further, the captain identified the flap anomaly to the extent necessary to select the applicable checklist procedure. The NTSB concludes that the captain was adequately trained on how to respond to flap anomalies and that the captain's statement that the airplane had "no flaps" indicates that he had sufficient information to recognize that he should immediately perform a go-around maneuver and apply the appropriate procedure from the QRH that applied to all flap problems.

Both the captain and the first officer had been trained to perform a go-around maneuver during an approach in which a stick shaker or TAWS warning occurred or an approach that became unstabilized. Multiple cues existed that indicated the approach was unstabilized, including excessive deviation from the glidepath (more than 300 feet right at 500 feet agl), sink rate greater than 1,000 fpm, and airspeed less than the required approach speed. The captain indicated that he made a judgment call to continue the landing because he was concerned about the flap anomaly and the icing conditions. However, the captain had extensive experience flying in icing conditions and was capable of assessing the effects of ice accretion on the airplane's performance. Because the airplane had shed ice from its first icing encounter during the descent into LBB, the captain should have recognized that a climb to 6,000 feet msl would have allowed the flight to exit icing conditions. Further, the flight crew had selected level 3 ice protection for the approach, and neither flight crewmember indicated that the ice accretion itself was worrisome before the flap anomaly occurred. The NTSB concludes that although the captain indicated that he was concerned about the icing conditions, the presence of airframe ice accretion within the capabilities of the airplane's systems does not negate the importance of adhering to SOPs and performing a go-around maneuver to respond to the multiple cues associated with an unstabilized approach including excessive deviation from the glidepath, sink rate greater than 1,000 fpm, and airspeed less than the required approach speed. Further, the NTSB concludes that, had the captain complied with SOPs in response to the flap anomaly, unstabilized approach, stick shaker, and TAWS warning and initiated a go-around maneuver, the accident likely would not have occurred.

2.3.2 Flight Crew's Failure to Monitor Airspeed

The dynamic nature of the approach phase of flight requires flight crews to monitor airspeed, and the presence of icing conditions requires an increased awareness of the airspeed because of the detrimental effects that icing can have on aircraft performance. According to the ATR 42 pilot handbook, during an ILS approach, the PM is to call out any deviations from normal altitude, airspeed, or descent rates. The QRH states that, during a non-normal event, the PF is responsible for the engine power levers, flightpath and airspeed control, aircraft configuration, and navigation, and the PM is responsible for completing the appropriate checklist items, actions on the overhead panel, condition levers, and communications.

During the 26 seconds from when the captain identified a flap problem to the first stick-shaker event, the airplane's airspeed decreased from about 155 kts (above the red-bug airspeed of 143 kts for a 0° flap approach in icing conditions) to 125 kts, and the first officer applied only a minimal adjustment of engine power during this time. As the airspeed decayed, neither flight crewmember made any verbal reference about airspeed (actual or target), and at no time did the captain call out the localizer, glideslope, airspeed, or vertical speed deviations.

Each pilot had two indicators available to assist with airspeed monitoring. First, each pilot had a fixed-scale, moving-pointer analog airspeed indicator. Each airspeed indicator had four airspeed bugs—yellow, white, red, and internal—that were manually set by each pilot based on predetermined airspeeds for the flight conditions.[100] The airspeed bugs for approach and landing in icing conditions should have been set at 121, 123, 143, and 116 kts, respectively. The captain erroneously briefed the bugs to be set at takeoff speeds in icing conditions, specifically 112, 123, 143, and 106 kts. The captain's bugs were set at 110, 124, 145, and 109 kts, and the first officer's bugs were set at 112, 124, 144, and 106 kts, respectively. Second, a fast/slow indicator was located on the left side of each pilot's EADI. The fast/slow indicator alerts the pilot of the airplane's actual airspeed in relation to the target airspeed set by the internal bug.

When the pilots realized that a flap anomaly had occurred, the appropriate airspeed to maintain would have been the red bug, or 143 kts. The crew could have reset the internal bug to this airspeed to have the additional airspeed cue from the EADI fast/slow indicator, but they did not do so. Previous accidents[101] have shown that pilots can become distracted from flying duties when an emergency or abnormal situation occurs, and literature suggests that "one of the biggest hazards of 'abnormals' is becoming distracted from other cockpit duties."[102] While flying the

[100] For more information about the airspeed bugs, see sections 1.6.4.1 and 1.17.1.4.

[101] (a) On December 29, 1972, a Lockheed L-1011 crashed when the flight crewmembers failed to monitor their flight instruments after becoming distracted by a malfunctioning landing gear position indicator, resulting in 101 fatalities. See *Eastern Air Lines, Inc., L-1011, N310EA, Miami, Florida, December 29, 1972,* Aircraft Accident Report NTSB/AAR-73/14 (Washington, DC: National Transportation Safety Board, 1973). (b) On June 9, 1995, a de Havilland DHC-8 crashed when the captain failed to monitor the approach after becoming distracted by first officer's attempts to reconcile a landing gear malfunction, resulting in 4 fatalities and 14 serious injuries. See *de Havilland DHC-8, ZK-NEY, Controlled Flight into Terrain, near Palmerston North, 9 June 1995,* Investigation Report 95-011 (Wellington, New Zealand: Transport Accident Investigation Commission, 1997). <http://www.taic.org.nz> (accessed March 21, 2011). (c) On April 19, 2008, a Cessna 510 overshot the runway during landing in Carlsbad, California, after the pilot became distracted by a flickering primary flight display and misjudged the airspeed and landing distance. The report for this accident, NTSB case number LAX08FA117, is available online at <http://www.ntsb.gov/aviationquery/index.aspx>.

[102] Dismukes, Young, and Sumwalt, pp 4-9.

approach, the first officer was likely distracted from monitoring the instruments by the flap anomaly, the captain's nonstandard actions involving the circuit breakers, and the control force inputs needed to maintain control of the airplane because of the flap asymmetry. Further, for the captain to check circuit breakers behind the first officer's seat, he would need to turn away from the instrument panel, a position from which monitoring the instruments was not possible. The NTSB concludes that the first officer's failure to maintain airspeed while acting as the PF likely resulted from being distracted by the flap anomaly, the captain's actions in response to it, and the control force inputs needed to maintain aircraft control. Further, the NTSB concludes that the captain's failure to call out the first officer's airspeed deviations resulted directly from his preoccupation with performing an inappropriate, nonstandard procedure in response to the flap anomaly.

2.3.2.1 Airspeed References

As previously mentioned, the airspeed bugs were not set properly because the captain did not correctly brief the airspeeds for an approach in icing conditions; instead, he erroneously briefed the airspeeds for a takeoff in icing conditions. It is not clear why neither crewmember recognized the captain's error; however, at the time of the accident, Empire Airlines did not have a procedure in place for flight crews to crosscheck and verify the setting of airspeed bugs. Empire Airlines has since implemented a crosscheck procedure. Also, because the captain did not perform the QRH procedure after identifying the flap anomaly, he did not brief the new approach speeds, and the flight crew did not reset the airspeed bugs accordingly.

Because the flight crew failed to properly set the internal airspeed bug, the EADI fast/slow indicator, which indicates the difference between the internal bug airspeed and the airplane's actual airspeed, provided indications that did not apply to the accident approach. However, the captain had correctly stated during his initial briefing that the airspeed for the red bug, which indicates the approach airspeed for 0° flaps in icing conditions, was 143 kts, and both red bugs were set near that value (144 and 145 kts). Therefore, the NTSB concludes that, although some of the airspeed bugs (including the internal bug) were not set to the appropriate approach airspeeds and were not reset following recognition of the flap anomaly, the flight crew had a sufficient reference to maintain the minimum safe airspeed because the airspeed for a no-flap approach in icing conditions was correctly briefed as 143 kts, and the red airspeed bugs were set near that value.

The airspeed indicator is a visual cue that can convey meaning to flight crewmembers only when they look at the indicator. As discussed previously, the first officer was distracted from monitoring the visual airspeed indications, and the captain's attention was focused away from the instrument panel. Evidence from this accident and others indicates that, in high-workload situations, a visual-only cue may not capture a pilot's attention due to human sensory limitations.

The airplane's stall protection system, which included an aural warning and tactile stick shaker, is designed to comply with Federal airworthiness standards, specifically

14 CFR 25.207,[103] that require airplanes be equipped to provide flight crews with a clear and distinctive stall warning at an airspeed that is about 7 percent higher than stall airspeed. When the flight crew became distracted by the flap anomaly and failed to detect that the airplane was approaching a stall, the stall protection system activated as designed and warned the flight crew of the decaying airspeed. However, the airspeed began to decay unnoticed much earlier during the approach. The airspeed indicator should have provided the pilots with adequate time to detect the ensuing low-airspeed regime and respond appropriately. However, distraction and workload considerations may have made it difficult for the flight crew to visually detect these cues. The NTSB concludes that reliance upon flight crew vigilance and stall warning systems may be inadequate to prevent hazardous low-airspeed situations and that, had a low-airspeed alerting system been installed on the airplane, it may have directed the flight crew's attention to the decaying airspeed earlier and provided an opportunity to take corrective action before the stall protection system activated.

The circumstances of this accident and the history of accidents involving flight crews' lack of low-airspeed awareness, most recently the flight crew of Colgan Air flight 3407,[104] suggest that flight crew vigilance and existing stall warnings may be inadequate to reliably prevent hazardous low-airspeed situations. In the Colgan Air accident, the pilots likely did not see the rising low-airspeed cue on the indicated airspeed display, the downward-pointing trend vector, or the airspeed indications change to red. As a result, the NTSB concluded that an aural warning in advance of the stick shaker would have provided a redundant cue of the visual indication of the rising low-airspeed cue and might have elicited a timely response from the pilots before the onset of the stick shaker. Therefore, the NTSB issued Safety Recommendation A-10-12,[105] which recommended that, for all airplanes engaged in commercial operations under 14 CFR Parts 121, 135, and 91 subpart K, the FAA require the installation of low-airspeed alerting systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-airspeed condition. Because of the FAA's inactivity regarding previous recommendations to require the installation of low-airspeed alerting systems, the NTSB classified Safety Recommendation A-10-12 "Open—Unacceptable Response" when it was issued on February 23, 2010.

Although the FAA has tasked the ARAC with developing recommendations for potential requirements to address low-airspeed alerting systems, progress remains slow, and the recommendation is still classified "Open—Unacceptable Response." This accident once again

[103] At the time the ATR 42 was certificated in 1988, 14 CFR 25.207(c) stated that "the stall warning must begin at a speed exceeding the stalling speed (i.e., the speed at which the airplane stalls or the minimum speed demonstrated, whichever is applicable under the provisions of 14 CFR 25.201(d)) by seven percent or at any lesser margin if the stall warning has enough clarity, duration, distinctiveness, or similar properties." The current version of 14 CFR 25.207(c) states that "when the speed is reduced at rates not exceeding one knot per second, stall warning must begin, in each normal configuration, at a speed, V_{SW}, exceeding the speed at which the stall is identified in accordance with 14 CFR 25.201(d) by not less than five knots or five percent CAS, whichever is greater. Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began."

[104] NTSB/AAR-10-01.

[105] For more information about Safety Recommendation A-10-12, see section 1.18.2.3.

demonstrates the need for low-airspeed alerting systems and provides additional support for this recommendation.[106]

2.3.2.2 Flight Crew Monitoring Skills and Techniques

The accident flight crew's deficiencies during the approach demonstrate the importance of active monitoring skills. However, the flight crew's CRM training did not specifically address the development of active monitoring skills.[107] The NTSB has long recognized the importance of flight crew monitoring skills in accident prevention. In 1994, the NTSB published a safety study[108] that reviewed 37 flight crew-related, major accidents involving U.S. air carriers and found that, for 31 of these accidents, inadequate monitoring and/or crosschecking had occurred. The safety 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 NTSB issued safety recommendations that resulted in upgrades of FAA training guidance, including revisions to AC 120-51B (currently AC 120-51E), "Crew Resource Management Training," and AC 120-71 (currently AC 120-71A), "Standard Operating Procedures for Flight Deck Crewmembers," to include references to the importance of flight crew monitoring functions. Subsequently, the NTSB issued Safety Recommendation A-07-13,[109] which asked the FAA to require that all pilot training programs contain modules that teach and emphasize monitoring skills and workload management and include opportunities to practice and demonstrate proficiency in these areas.

On May 17, 2007, the FAA stated that it would consider identifying in its work program a list of required inspections, reemphasizing to the regional and FSDO managers the need to validate the training and to verify its effectiveness. However, the FAA's lack of progress in this area and the February 12, 2009, Colgan Air accident[110] in which the flight crew failed to monitor airspeed prompted the NTSB to reiterate Safety Recommendation A-07-13 and reclassify it "Open—Unacceptable Response" on February 23, 2010. On the same date, the NTSB issued Safety Recommendation A-10-10,[111] which asked the FAA to require 14 CFR Part 121, 135, and 91 subpart K operators to review their SOPs to verify that they are consistent with the flight crew monitoring techniques, as described in AC 120-71A. On June 22, 2010, the FAA responded that it was considering issuing a SAFO or an InFO bulletin to address this recommendation. On January 25, 2011, the NTSB indicated that, although such action may represent part of an acceptable response to this recommendation, the FAA must also ensure that the guidance provided in documents like SAFOs is implemented. This accident again demonstrates the importance of flight crew monitoring skills in accident prevention and provides additional support for Safety Recommendations A-07-13 and A-10-10.

[106] For information about ATR's APM technology that provides icing-specific airspeed alerts, see section 2.6.1.

[107] For information about other CRM topics, see section 2.3.3.

[108] NTSB/SS-94/01.

[109] For more information about Safety Recommendation A-07-13, see section 1.18.2.1.

[110] NTSB/AAR-10/01.

[111] For more information about Safety Recommendation A-10-10, see section 1.18.2.1.

2.3.3 Crew Resource Management

During the accident flight's initial descent, the flight crew demonstrated several instances of good CRM; the captain completed the descent checklist and immediately began the approach checklist in anticipation of the first officer's needs. However, after the flap anomaly was recognized, the flight crew's CRM deteriorated to the extent that the captain did not provide adequate leadership in response to the anomaly. Further, the first officer was not assertive in voicing her concerns about the captain's nonstandard response or his decision to continue the unstabilized approach. The captain is responsible for setting the tone in the cockpit for the entire flight, and this responsibility was even more critical because the flight crew was faced with an abnormal situation.

The accident captain had about 13,935 total flight hours (2,052 hours of which were in the ATR 42) and extensive experience flying in icing conditions. He had previously served as a check airman on the company's single-pilot Cessna 208 airplanes. The first officer had about 2,109 total flight hours (130 hours of which were as SIC in the ATR 42) and very limited experience flying in icing conditions. The captain had been with Empire Airlines for more than 20 years.Thus, he should have been very familiar with the company's SOPs, and the accident flight crew should have been able to benefit from the captain's extensive experience with the company, in ATR 42 airplanes, and with flying in icing conditions. However, the captain failed to command control of the situation and follow SOPs. Following identification of the flap anomaly, the captain did not communicate to the first officer his intentions for managing the situation. Instead, the captain pursued his own plan of action without providing any guidance to the first officer or performing the duties required of him as the PM, which could have helped the first officer manage the airplane during the approach.

The large disparity between the captain's and the first officer's flying experience, their experience in the ATR 42, and their experience in icing conditions likely created a steep authority gradient in the cockpit. The flight crewmembers who flew with the captain stated in interviews that, overall, he was very experienced, a good pilot, and a good captain. He was referred to as a "guru." The issue of cockpit authority gradient has been examined since the late 1970s and has been evident in a number of major aviation accidents, including the March 27, 1977, collision of two Boeing 747s at Tenerife Airport, Los Rodeos, Spain.[112] Evidence has suggested that too steep of a gradient can reduce flight crew performance, hinder communication, and increase errors. For example, a review of U.S. Navy mishaps between 1980 and 1990 revealed that flight crews with an authority gradient of one rank or more between flight crewmembers had 21 percent more errors than flight crews in which the crewmembers were of the same rank.[113] In a study of 249 airline pilots in the United Kingdom, nearly 40 percent of first officers stated that they failed to communicate safety concerns to their captains on more

[112] See *KLM B-747, PH-BUF, and Pan Am B-747, N736PA, Collision at Tenerife Airport, Los Rodeos, Spain, on 27 March 1977*, Aircraft Accident Report (Spain: Subsecretaría de Aviación Civil, 1978).

[113] R.A. Alkov and others, "The Effect of Trans-Cockpit Authority Gradient on Navy/Marine Helicopter Mishaps," *Aviation, Space, and Environmental Medicine*, vol. 63, no. 8 (1992), pp. 659-661.

than one occasion for reasons that included a desire to avoid conflict and deference to the captain's experience and authority.[114]

The poor CRM observed in this accident is similar to that which the NTSB found during its investigation of the February 19, 1996, crash of Continental Airlines flight 1943 in Houston, Texas.[115] During the event sequence leading to the accident, the captain rejected, without any discussion, the first officer's go-around request, and the first officer failed to challenge his decision. The flight crew failed to complete multiple checklists and continued an unstabilized approach below 500 feet[116] against company procedures to go around in such situations. As a result of this accident, the NTSB issued Safety Recommendations A-97-05 and -06,[117] which asked the FAA to require all POIs of 14 CFR Part 121 carriers to 1) ensure that the carriers establish a policy and make it clear to their pilots that there will be no negative repercussions for appropriate questioning in accordance with CRM techniques of another pilot's decision or action and 2) ensure that CRM programs provide pilots with training in recognizing the need for, and practice in presenting, clear and unambiguous communications of flight-related concerns.

On October 30, 1998, the FAA issued AC 120-51C (currently AC 120-51E), which emphasized the importance of all levels of management to support a safety culture that promotes communication by encouraging appropriate questioning and that there will be no negative repercussions for appropriate questioning of one pilot's decision or action by another. Based on the FAA's lack of action to issue an FSIB, on February 23, 2000, the NTSB classified these recommendations "Closed—Unacceptable Action." Thirteen years after the FAA issued AC 120-51C, the NTSB continues to investigate accidents in which one pilot does not question the actions or decisions of another pilot.

To overcome large authority gradients, AC 120-51E suggests that assertiveness be included in CRM training programs. FlightSafety's CRM training materials for Empire Airlines' flight crewmembers included two presentation slides that encouraged pilots to speak up with "appropriate persistence until there is a clear resolution." However, the accident first officer could not recall what was trained during the 2-day CRM training course, including whether or not assertiveness was addressed.

According to Empire Airlines' ATR 42 pilot handbook, if a go-around maneuver is required, the PF should call out "go around" and initiate the go-around procedures. During the accident flight, the first officer instead asked the captain, "should I go around?," rather than directly asserting her concern about the unstabilized approach, even though she was aware that company policy was to go around in the event of stick-shaker activation. The first officer indicated that asking was her way of saying that she wanted to go around "without stepping on toes." Captains who had previously flown with the first officer stated that, although she did not seem to have a problem standing up for something in the cockpit, she asked a lot of questions when flying that were related to skills that she already knew.

[114] J. Wheale, "Crew Coordination on the Flight Deck of Commercial Transport Aircraft," *Proceedings of the Flight Operations Symposium, October 1983* (Dublin: Irish Air Line Pilots Association/Aer Lingus, 1983).

[115] NTSB/AAR-97/01.

[116] A ground proximity warning system alert continued below 200 feet above field elevation.

[117] For more information about Safety Recommendations A-97-05 and -06, see section 1.18.2.4.

The first officer stated that, after the captain responded "no" to her go-around inquiry, she felt that he had a good reason for not wanting to go around and that she trusted that he was making the right decisions. The first officer stated that, after the captain took control of the airplane, she was still concerned with the approach and felt that she should have called again for a go-around maneuver but that she did not know why she did not say anything. The NTSB concludes that the first officer's failure to assert herself to the captain and initiate a go-around maneuver when she recognized the unstabilized approach likely resulted from the steep authority gradient in the cockpit and the first officer's minimal training on assertiveness; further, the captain's quick dismissal of the first officer's go-around inquiry likely discouraged the first officer from voicing her continued concerns and challenging the captain's decision to continue the unstabilized approach. The NTSB notes that the first officer's CRM training did not include any role-playing activities in which pilots could practice developing assertiveness skills. Practice allows pilots to bridge the gap between their knowledge of assertiveness and the actions needed in the cockpit to effectively be assertive.[118] The NTSB concludes that role-playing exercises are essential for effective assertiveness training because such exercises provide flight crews with opportunities for targeted practice of specific behaviors and feedback that a lecture-based presentation format lacks. Therefore, the NTSB recommends that the FAA require that role-playing or simulator-based exercises that teach first officers to assertively voice their concerns and that teach captains to develop a leadership style that supports first officer assertiveness be included as part of the already required CRM training for 14 CFR Part 121, 135, and 91 subpart K pilots.

2.3.4 Go-Around Callout

Empire Airlines' ATR 42 pilot handbook specified that the phrase "go around" is to be stated out loud by the PF; however, the operating procedures did not provide any guidance indicating that the PM could initiate the same action. Similarly, Empire Airlines' flight training materials contained no guidance that indicated whether either pilot could call for a go-around maneuver, if necessary.

During the NTSB's investigation of the February 18, 2007, Shuttle America runway overrun accident,[119] the NTSB noted that it is critical to flight safety that either flight crewmember be able to call for a go-around maneuver if either pilot believes that a landing would be unsafe. As a result, the NTSB issued Safety Recommendation A-08-18,[120] which asked the FAA to require operators to have a written policy emphasizing that either pilot can make a go-around callout and that the proper response to such a callout is an immediate missed approach. On March 1, 2010, the FAA issued SAFO 10005, "Go-Around Callout and Immediate Response," which recommended that operators provide such a written policy. However, the FAA has not yet revised FAA Order 8900.1 to include guidance to POIs to have operators develop the written policy and has not yet completed a survey to ensure that all operators have developed and

[118] R.L. Beard, E. Salas, and C. Prince, "Enhancing Transfer of Training: Using Role Play to Foster Teamwork in the Cockpit," *International Journal of Aviation Psychology*, vol. 5, no. 2 (1995), pp. 131-143.

[119] NTSB/AAR-08/01.

[120] For more information about Safety Recommendation A-08-18, see section 1.18.2.2.

implemented this policy. The NTSB encourages the FAA to take timely action in response to this recommendation.

2.3.5 Training for Single and Multiple Abnormal Situations Occurring at Low Altitude

As this accident shows, pilots can encounter rapidly changing conditions during approach-to-landing operations. The accident flight crew encountered a flap asymmetry while operating in moderate icing conditions. (Moderate icing conditions, although considered a normal situation in the AFM, increase flight crew workload.) Because any distraction from maintaining airplane controllability at low altitude can lead to dire consequences, pilots must be familiarized with the rapid decision-making and maneuvering skills required to ensure safe flight, especially when operating near the ground. During the accident flight, the captain remained committed to continuing the approach, even though he was trained that (and SOPs required that) a go-around maneuver should be performed and even after he received multiple indications that the approach had become dangerously unstabilized.

After the accident, the captain explained that he "just wanted to land as soon as possible." The 1998 NASA study[121] found that the most common decision errors occurred when the flight crew decided to "continue with the original plan of action in the face of cues that suggested changing the course of action." The NASA study stated that the cues that signal a problem are not always clear and that a decision maker's assessment of the situation may not keep pace with conditions that deteriorate gradually. The NASA study also indicated that individuals have a natural tendency to maintain their originally selected course of action until clear and overwhelming evidence exists that the course of action should be changed. In addition, the study noted that pilots under stress might not evaluate the consequences of various options.

On May 19, 2009, as a result of the NTSB's investigation of the September 28, 2007, American Airlines flight 1400 accident,[122] which involved multiple, simultaneous abnormal situations, the NTSB issued Safety Recommendations A-09-24 and -25,[123] which asked the FAA to establish best practices for conducting both single and multiple emergency and abnormal situations training and to require that these best practices be incorporated into all operators' approved training programs. Although the FAA has made progress by publishing its January 12, 2009, NPRM, "Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers,"[124] which included scenario-based training for all 14 CFR Part 121 carriers, the NTSB is concerned that, without a guide to best practices, inspectors and operators will have difficulty creating effective programs. The FAA has not yet completed a review of the regulatory and policy framework to determine whether additional guidance or requirements are necessary.

[121] J. Orasanu, L. Martin, and J. Davison, *Errors in Aviation Decision Making: Bad Decisions or Bad Luck?*, NASA Ames Research Center, Moffett Field, California. Presented to the Fourth Conference on Naturalistic Decision Making, Warrenton, Virginia, May 29-31, 1998.

[122] NTSB/AAR-09/03.

[123] For more information about Safety Recommendations A-09-24 and -25, see section 1.18.2.1.

[124] 74 FR 1280. (The FAA subsequently began work on an NPRM supplement, which was submitted to the Office of Management and Budget (OMB) for review on November 29, 2010. As of the date of this report, OMB is continuing to review this supplemental NPRM with no projected completion date.)

The NTSB recognizes that operators have limited time to allocate to training. However, this accident and others show that pilots could benefit from opportunities to develop the skills and decision-making abilities needed during single and multiple abnormal situations; such training can present pilots with competing task demands and increased workloads and can demonstrate in a safe environment the possible consequences of not taking timely, appropriate corrective action. This accident illustrates that these skills are most important at low altitudes when rapid, accurate assessment of abnormal situations and appropriate prioritization of tasks are the most critical. Thus, the NTSB concludes that the establishment of best practices for conducting both single and multiple emergency and abnormal situations training needs to include training for the occurrence of these situations at low altitudes because low-altitude scenarios require rapid, accurate assessment of abnormal situations and appropriate prioritization of tasks. The circumstances of this accident reinforce the need for the actions recommended in Safety Recommendations A-09-24 and -25, and the NTSB encourages the FAA to take timely action in response to these recommendations.

2.3.6 Fatigue Considerations

The NTSB evaluated a number of criteria[125] to determine the extent to which fatigue impacted the flight crew's performance during the accident sequence including circadian factors, sleep length, and time awake.

The accident occurred about 0437, and the flight crewmembers were awake in opposition of their normal circadian rhythm. For those entrained on a diurnal schedule, the primary circadian trough is about midnight to 0600, with the window of circadian low generally occurring between about 0300 and 0500. The aeromedical research community has identified strategies that flight crews can use to lessen the adverse effects of fatigue during required overnight operations. These strategies include avoiding morning sunlight and staying indoors, ensuring the daytime sleep environment is dark and cool, wearing eye masks and earplugs during daytime sleep, implementing good sleep habits, taking a short nap before reporting for duty, allowing exposure to at least 2 hours of sunlight or bright artificial light in the late afternoon or early evening after waking, strategically using caffeine, and getting regular exercise.[126] Both flight crewmembers took some actions before the accident to reduce the likelihood of performance decrements associated with being awake during the nighttime hours.

For example, during the week before the accident flight (January 20 through 23), the first officer had a scheduled trip in which she was on duty during the night hours beginning about 0045. She was off duty from the afternoon of January 23 through the evening of January 26. Empire Airlines paid her expenses to spend the weekend in Midland, Texas, rather than commuting back to her home in Washington for a short turnaround.[127] The first officer stated

125 Information regarding the NTSB's methodology for investigating operator fatigue is available online at <http://www.ntsb.gov/info/fatigue_checklist_V%202_0.pdf>.

126 M. Caldwell and others, "Fatigue Countermeasures in Aviation," *Aviation, Space, and Environmental Medicine,* vol. 80, no. 1 (2009), pp. 29-59.

127 The flight crew was based in Salt Lake City, which was considered to be a "floater" base. The flight crewmembers would travel to various cities based on the needs of the company, which paid their expenses over the weekend.

that because she had acclimated herself to sleeping during the days and being awake at night for the previous trip, she remained on that sleep/wake schedule during her off-duty days rather than resetting her circadian rhythm to a diurnal pattern of being awake during the day and sleeping at night. During the 3 days before the accident, the first officer indicated that she went to bed about 0600 and awoke between about 1400 and 1500, providing a sleep opportunity each night of between 8 and 9 hours.[128] Based on these times, the first officer went to bed before sunrise, thus avoiding morning sunlight, and awoke before sunset, allowing exposure to bright daylight before reporting for duty, which would have contributed to her ability to shift her circadian clock.[129] Research suggests that adjustment to night activity is possible, and, under ideal conditions, the adjustment occurs about 1 hour per day.[130] However, a NASA study examining pilots in overnight cargo operations found that the circadian clock of pilots did not shift completely as measured by temperature minimums;[131] the circadian low was delayed about 3 hours after 5 days of night flying.[132] Although the first officer's efforts to adapt to an overnight schedule suggest an individual awareness of the need to mitigate fatigue hazards associated with overnight operations, and the first officer was possibly able to delay her window of circadian low to some degree, it is unlikely, based on the available research data, that her efforts would have completely mitigated the circadian effects of fatigue associated with the time at which the accident occurred.

Sleep needs vary by individual. In postaccident interviews, the first officer stated that she needed 7 hours of sleep to feel rested. In the 72 hours before the accident, she had 25.5 hours of sleep opportunity (8.5 hours, 8 hours, and 9 hours in the previous three nights). She indicated that she felt rested on the evening of the accident. The first officer's sleep schedule during her previous trip is unknown. The NASA study examining pilots in overnight cargo operations found that, while on duty, 54 percent slept over 1 hour less per 24 hours than they did on pre-trip days, 29 percent slept over 2 hours less per 24 hours than they did on pre-trip days, and 15 percent averaged more sleep per 24 hours than they did on pre-duty days.[133] Post-duty days allowed pilots to recuperate some of their lost sleep. Specifically, the pilots in the study slept 41 minutes longer per 24 hours during post-duty days than pre-trip days and 1.9 hours longer per 24 hours during post-duty days than duty days. Although the first officer had sleep opportunities in excess of the hours of sleep she needed to feel rested during her off-duty days and had the opportunity to recuperate any sleep debt accrued, it is unknown as to how much sleep she actually received. Therefore, it cannot be determined whether the first officer had accumulated a sleep debt during the week before the accident.

[128] The first officer stated that she needed 7 hours of sleep per night to feel rested.

[129] Night conditions would have prevailed at the time of the first officer's reported bedtime, which was more than 1 hour before sunrise in Midland, Texas. For the week before the accident, sunrise ranged from about 0745 to 0748, and sunset ranged from about 1810 to 1817.

[130] R. Wever, "Phase Shifts of Circadian Rhythms due to Shifts of Artificial *Zeitgebers*," *Chronobiologia*, vol. 7 (1980), pp. 303-327.

[131] Core body temperature minimums typically occur in the circadian trough and can be associated with sleep tendency. Caldwell and others, p. 42.

[132] P.H. Gander and others, "Flight Crew Fatigue IV: Overnight Cargo Operations," *Aviation, Space, and Environmental Medicine*, vol. 69, no. 9 (1998), pp. B26-B36.

[133] Gander and others, pp. B28-B29.

At the time of the accident, the first officer had been awake about 13.5 hours. Research into quantifying performance impairment associated with sustained wakefulness found that performance remains relatively stable throughout the time that coincides with a normal waking day, but that prolonged wakefulness of 17 hours can result in measurable performance impairment (comparable to having a blood alcohol concentration of 0.05 percent).[134] The first officer did not have such prolonged or otherwise excessive periods of wakefulness before the accident.

The captain also took steps to minimize the effects of fatigue due to the circadian clock. On the night before the accident trip, the captain went to sleep about 2200 but, to prepare himself for the upcoming night flight, awoke about 0400 on January 26, 2009. Later that afternoon, he napped from about 1100 to 1630, providing a 5.5-hour sleep opportunity. The captain stated that he needed 6 to 8 hours of sleep each night to feel rested. In the 72 hours before the accident, the captain had 22 hours of sleep opportunity (10 hours, 6 hours, and 5.5 hours). The captain stated that he felt rested on the evening of the accident. Although research suggests that appropriately placed naps can improve alertness for up to 24 hours,[135] because the accident occurred during the window of circadian low, the captain was likely experiencing some fatigue at the time of the accident. In addition, if the captain required 8 hours of sleep per night to feel rested, he may have been experiencing as much as 4.5 hours of cumulative sleep loss on the night of the accident. Research suggests that as few as 2 hours of sleep loss can lead to reduced performance and alertness.[136] At the time of the accident, the captain had been awake about 12 hours, which would not be considered excessive.

2.3.6.1 Role of Fatigue in Flight Crew Performance

The negative effects of fatigue on human performance have been demonstrated in scientific research and accident and incident investigations.[137] These effects include slowed response time, reduced vigilance, and poor decision making. The flight crew's failure to monitor

[134] (a) D. Dawson and K. Reid, "Fatigue, Alcohol and Performance Impairment," *Nature*, vol. 388, no. 6639 (1997), p. 235. (b) N. Lamond and D. Dawson, "Quantifying the Performance Impairment Associated with Sustained Wakefulness" (Woodville, South Australia: The Centre for Sleep Research, The Queen Elizabeth Hospital, 1998). <http://cf.alpa.org/internet/projects/ftdt/backgr/Daw_Lam.html> (accessed March 21, 2011).

[135] D.F. Dinges and others, "Temporal Placement of a Nap for Alertness: Contributions of Circadian Phase and Prior Wakefulness," *Sleep*, vol. 10, no. 4 (1987), pp. 313-329.

[136] R. T. Carskadon, "Sleep Restriction," ed., *Sleep, Sleepiness and Performance*, T. H. Monk, ed. (Chichester, England: John Wiley & Sons, 1991), pp. 155–167.

[137] For the scientific research, see J.A. Caldwell, "Fatigue in the Aviation Environment: An Overview of the Causes and Effects as Well as Recommended Countermeasures," *Aviation, Space, and Environmental Medicine*, vol. 68 (1997), pp 932-938; G.P. Kruger, "Sustained Work, Fatigue, Sleep Loss, and Performance: A Review of the Issues," *Work and Stress*, vol. 3 (1989), pp 129-141; and F.H. Previc and others, "The Effects of Sleep Deprivation on Flight Performance, Instrument Scanning, and Physiological Arousal in Pilots," *The International Journal of Aviation Psychology*, vol. 19, no. 4 (2009), pp. 326-346. For the accident investigations, see, for example, *Crash During Attempted Go-Around After Landing East Coast Jets Flight 81 Hawker Beechcraft Corporation 125-800A, N818MV Owatonna, Minnesota July 31, 2008*, Aircraft Accident Report NTSB/AAR-11/01 (Washington, DC: National Transportation Safety Board, 2011). <http://www.ntsb.gov/Publictn/2011/AAR-11-01.pdf>; *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: National Transportation Safety Board, 2006). <http://www.ntsb.gov/publictn/2006/AAR0601.pdf>.

the airplane's airspeed following the flap anomaly could be consistent with the known effects of fatigue; however, this type of error has also been made by flight crews who were not fatigued.

Throughout the flight, the first officer demonstrated good performance, including correcting the captain when setting up the approach, questioning the meaning of the Mu readings provided by ATC, and identifying the need to execute a go-around maneuver after the stall warning activated. Her failure to monitor airspeed and maintain a stabilized approach did not occur until after the flap anomaly, while the captain was performing a nonstandard troubleshooting procedure. The first officer queried the captain as to whether she should go around, and he told her "no." The first officer was flying an airplane in which she had little experience and in conditions that she had never before experienced. As a result, the first officer relied on the captain's leadership and experience for guidance, and his instructions to continue the unstabilized approach contradicted SOPs and likely contributed to her failure to assert her concerns further. In addition, the captain failed to delegate duties in the abnormal situation, and his nonstandard approach to address the flap anomaly likely distracted her from her PF duties. The NTSB concludes that, although the risk for fatigue existed at the time of the accident due to the window of circadian low, the first officer took steps to mitigate the effects of fatigue, and her errors during the flight can be explained by her lack of experience in both the airplane and in icing conditions along with the distraction caused by the captain's nonstandard response to the flap anomaly.

Unlike the first officer, the captain made a number of errors throughout the flight, including briefing the incorrect approach airspeeds, failing to monitor the first officer's approach, and performing a nonstandard and nontrained procedure in response to the flap anomaly. The captain's decision not to follow SOPs for checklist usage and the unstabilized approach might be explained through his actions demonstrated on previous flights (another pilot had indicated that the captain occasionally cut corners, seemed rushed, and was less thorough on briefings than other captains) and the stress associated with the situation. However, the captain's repeated errors and decision to forego procedures might also reflect degradation from fatigue as a result of performing during a time when he was normally asleep, as well as performing with a sleep debt. The NTSB concludes that, due to the early morning hour of the accident flight and the captain's cumulative sleep debt, fatigue likely degraded the captain's performance. The NTSB notes that careful adherence to SOPs, including strict adherence to accepted practices of stabilized approach criteria, non-normal procedures, and CRM, can help flight crews mitigate the degrading effects of fatigue. The NTSB further notes that neither the captain nor the first officer received specific training from their company addressing the hazards of fatigue or fatigue mitigation, although fatigue was briefly addressed during CRM training.

On September 10, 2010, the FAA addressed some aspects of fatigue by issuing an NPRM titled "14 CFR Parts 117 and 121: Flightcrew Member Duty and Rest Requirements," which proposes to amend Part 121 and establish Part 117 to create a single set of flight time limitations, duty period limits, and rest requirements for Part 121 operations. The NPRM also proposes requiring a fatigue education and training program for all flight crewmembers, employees involved in operational control and scheduling of flight crewmembers, and personnel having management oversight of these areas. The FAA is currently drafting AC 120-FT, "Fatigue Training," that will present guidelines for developing and implementing a fatigue training program. The draft guidance outlines a training program that includes, in part, a review of the basics of fatigue, including an overview of circadian rhythms, the causes of fatigue, the effect of fatigue on performance, fatigue countermeasures and mitigation, and lifestyle influences on fatigue.

On November 15, 2010, the NTSB commented on the NPRM and stated, “if adopted, the proposed rule will provide substantial benefits towards reducing the hazards associated with flight crew fatigue in Part 121 operations.” The NTSB also stated its strong support for the requirement of a fatigue education and training program, noting that fatigue education is among the foundational elements of an effective fatigue management system.

The NTSB is encouraged by the FAA’s response to fatigue mitigation for Part 121 operations based on the NPRM. In recent years, a number of accidents involving Part 121 operators have occurred in which fatigue was causal, contributory, or identified as a safety issue. The NTSB believes that finalizing the rule in a timely fashion will provide substantial benefits towards reducing the hazards associated with flight crew fatigue in Part 121 operations and is critical to aviation safety.

2.4 Operations Issues

2.4.1 Dispatch into Freezing Drizzle Conditions

The flight release for the accident flight contained weather information that indicated that IFR conditions with light freezing drizzle and mist were reported at LBB and that such conditions were forecast to continue beyond the flight’s estimated time of arrival. During the flight’s descent toward LBB, the controller informed the flight crew that light freezing drizzle and mist were reported at the airport.

Although SLD conditions like freezing rain or freezing drizzle are outside the ATR 42’s certification icing envelope as specified in 14 CFR Part 25, Appendix C, the FAA does not specifically prohibit operators from dispatching or operating airplanes in such weather conditions. Instead, the FAA requires that operators adhere to any AFM limitations for the airplanes that they operate. The NTSB has long been concerned about such operations and issued numerous safety recommendations in the 1980s[138] and the 1990s[139] related to the issue. In response to these recommendations, the FAA issued an NPRM.[140]

For the ATR 42, the AFM states that a flight crew must immediately exit severe icing conditions when they are encountered. According to Empire Airlines’ GOM, “when light freezing rain, light or moderate freezing drizzle, or light, moderate, or heavy snow is falling, aircraft may land.” The GOM also stated that, “when light freezing rain, light to moderate freezing drizzle, or light, moderate snow is falling, [an ATR] aircraft may take off, provided it is prepared in accordance with approved deicing procedures.”

[138] NTSB/SR-81/01.

[139] NTSB/AAR-96/01.

[140] For more information about the NPRM, see section 2.4.1.2.

After the accident, on February 27, 2009, Empire Airlines issued a flight operations bulletin to supersede the icing information in the GOM and to inform flight crews and flight followers that freezing rain and freezing drizzle are not covered by the icing certification envelope and that takeoff or landing operations in known or reported freezing rain or freezing drizzle of any intensity are prohibited. An informal review of other 14 CFR Part 121 and 135 operators' icing guidance revealed that the operators' guidance for dispatching their turbine-powered, pneumatic deice boot-equipped airplanes into freezing rain and freezing drizzle conditions varied widely; some operators prohibited dispatch into such conditions, and others permitted it.

As this accident shows, moderate icing conditions due to light freezing drizzle can increase a flight crew's workload and degrade the performance of the airplane. Although Empire Airlines and the other FedEx feeder operators developed "no-go" weather guidance (after the accident) that prohibits takeoff or landing operations in known or reported freezing rain or freezing drizzle, these actions were not required by the FAA, and other operators may not adopt such safety measures. The NTSB concludes that dispatching and operating an airplane in known icing conditions for which the airplane is not certificated and has not demonstrated the ability to operate safely has the potential to reduce or eliminate safety margins. Therefore, the NTSB recommends that the FAA prohibit all 14 CFR Part 121, 135, and 91 subpart K operators of pneumatic deice boot-equipped airplanes from dispatching or deliberately operating these airplanes in known freezing rain or freezing drizzle of any intensity, unless the airplane manufacturer has demonstrated that the airplane model can safely operate in those conditions.

2.4.1.1 Flight Crewmember and Dispatcher Training Related to Icing Conditions

According to Empire Airlines' director of operations, the GOM information in place before the accident (which permitted dispatching and operating airplanes in light freezing rain; light or moderate freezing drizzle; or light, moderate, or heavy snow) was developed based on information from the ADP holdover tables. However, the NTSB notes that holdover tables are references that are used for ground deicing operations and are not intended to be used to address the in-flight icing environment.[141]

Interviews with Empire Airlines' flight followers and the dispatch manager revealed that their perceptions about dispatching into freezing drizzle conditions were based on this GOM and ADP information. However, such guidance based on ground deicing operations did not emphasize the potential dangers of in-flight encounters with freezing rain and freezing drizzle that are described in airplane-specific flight operations publications. For example, the AFM for the airplane (which is a flight publication provided by ATR) contained the following warning:

> Severe icing may result from environmental conditions outside of those for which the airplane is certificated. Flight in freezing rain, freezing drizzle, or mixed icing

[141] In the section of the March 2011 edition of *Cold Weather Operations: Be Prepared for Icing* that discusses ground deicing, ATR states, in part, the following: "IMPORTANT: The fluids used during ground de/anti-icing is not intended for and does not provide protection during the flight. Before take-off, pilots must be aware of potential in-flight severe icing conditions…. If such conditions exist, take-off must be delayed"

> conditions (supercooled liquid water and ice crystals) may result in ice buildup on protected surfaces exceeding the capabilities of the ice protection system.

Also, ATR's *Cold Weather Operations* publication[142] stated that in-flight icing is a major concern for commuter airplanes (which are typically pneumatic deice boot-equipped airplanes) in particular because they fly at altitudes where icing conditions are most likely to occur. Neither of these flight publications was used in developing dispatch guidance.

Based on information obtained during interviews with flight crewmembers and dispatch personnel, the NTSB found that many were not sufficiently aware of the dangers of operating in freezing drizzle precipitation and lacked a thorough understanding of the weather phenomena associated with SLD conditions. Although on March 16, 2010, the FAA issued SAFO 10006, which referenced several of the NTSB's safety recommendations that resulted from its investigation of the October 31, 1994, accident in Roselawn, Indiana,[143] to encourage all operators to review and amend, if necessary, their flight crewmember and dispatcher training programs to ensure that their programs address SLD icing conditions, the actions recommended in a SAFO are not mandatory. Also, as noted previously, other operators' dispatch guidance varied, and Empire Airlines erroneously relied on ground deicing guidance as the basis for dispatch decisions, which resulted in assumptions that led to the dispatch of flights into freezing drizzle without adequate consideration for the in-flight hazards associated with the conditions.

The NTSB is concerned that disparity exists between operators' and airplane manufacturers' guidance materials and between the guidance materials of operators of similar airplanes regarding flight operations in SLD conditions, particularly after the NTSB issued numerous safety recommendations on the topic resulting from its investigation of the October 31, 1994, accident in Roselawn, Indiana.[144] Dispatch personnel like Empire Airlines' flight followers who authorize each flight release, provide preflight weather products, and perform flight following share an integral role with flight crews in ensuring that each flight safely reaches its destination. The NTSB concludes that, to most effectively ensure the safety of flight operations in icing conditions, pilots, dispatchers, and flight followers must understand how the dangers of freezing drizzle and freezing rain can affect their airplanes and must understand the differences between ground deicing considerations and in-flight icing operations. Therefore, the NTSB recommends that the FAA review the approved pilot, dispatcher, and flight follower training programs and procedures for all 14 CFR Part 121, 135, and 91 subpart K operators and require revisions to the programs and procedures, as necessary, to include standardized training and aircraft-specific information to educate pilots, dispatchers, and flight followers of the dangers of flight operations in freezing precipitation and of the differences between ground deicing considerations and in-flight icing operations.

[142] *Cold Weather Operations: Be Prepared for Icing* (2008).

[143] NTSB/AAR-96/01.

[144] NTSB/AAR-96/01.

2.4.1.2 Proposed Rulemaking for Airplane Certification Requirements for Flight in Icing Conditions

In response to several NTSB safety recommendations, on June 29, 2010, the FAA issued an NPRM[145] intended to improve the safety of transport-category airplanes operating in SLD, mixed-phase, and ice-crystal icing conditions. The NPRM included proposals for expanding the certification icing environment for newly certificated transport-category airplanes to include freezing rain and freezing drizzle and for requiring airplanes most affected by SLD icing conditions to meet certain safety standards in the expanded certification icing environment, including additional airplane performance and handling requirements.

On August 27, 2010, in comments submitted to the docket for this NPRM, the NTSB stated that it was pleased that the NPRM proposed to add new sections to 14 CFR Part 25. Specifically, the NTSB noted section 25.1420, which would require aircraft manufacturers to evaluate airplane operation in the SLD environment, and Appendix O, Part I, which would expand the certification icing environment to include freezing rain and freezing drizzle by using four separate droplet-size distributions. Additionally, the NTSB stated that it was pleased to see the inclusion of Appendix O, Part II, which states the following:

> The most critical ice accretion in terms of airplane performance and handling qualities for each flight phase must be used to show compliance with the applicable airplane performance and handling qualities requirements for icing conditions contained in Subpart B of this part. Applicants must demonstrate that the full range of atmospheric icing conditions specified in Part I of this appendix have been considered, including drop diameter distributions, liquid water content, and temperature appropriate to the flight conditions.

Although the NTSB finds that several aspects of the FAA's NPRM are essential for improving the safety of flight for airplanes operating in icing conditions, the NTSB is disappointed that the proposed rule applies only to newly certificated aircraft (thus, the accident airplane would not be subject to the new rules) and that it excludes certain aircraft (such as those with a maximum takeoff weight of more than 60,000 lbs or irreversible flight controls) from compliance with the new safety standards. In its response, the NTSB noted that SLD conditions can present a danger for the current fleet of aircraft; therefore, the proposed rule should be expanded beyond newly certificated airplanes to include all deice boot-equipped airplanes currently in service that are certificated for flight in icing conditions.

2.4.2 Training Program and Manual Discrepancies

Empire Airlines personnel indicated that, during basic indoctrination training, pilots reviewed the ADP, FAA's meteorology handbook, and icing videos. Empire Airlines personnel also indicated that, during training at FlightSafety, pilots reviewed the ATR *Cold Weather Operations* publication[146] and reviewed meteorological conditions likely to cause freezing

[145] 75 FR 37311-37339.

[146] *Cold Weather Operations: Be Prepared for Icing* (2008).

drizzle and freezing rain. However, Empire Airlines' FTM included a document that indicated that Empire Airlines (not FlightSafety) was required to provide the required meteorology training, including the ATR publication, as part of the meteorology module. Interviews with FlightSafety instructors revealed that they were not providing or using the publication during training. The flight crew did not recall receiving this document.

Although Empire Airlines implemented special emphasis icing training for all ATR pilots after the accident, the NTSB had concerns that the FAA did not detect these training program discrepancies before the accident. Spokane FSDO personnel managed their oversight of Empire Airlines through the FAA's ATOS program. A review of the ATOS program table, "System/Subsystem/Element Chart—Operations and Cabin Safety Elements," revealed that, as part of the program, the FAA was required to provide oversight of an airline's FTM content and flight crewmember training. However, the inspectors who followed the ATOS program did not detect that Empire Airlines was not providing the required meteorology training, including the ATR publication, as part of the meteorology training module. Upon learning of this, the FAA contacted the certificate management offices of other ATR operators and determined that this was an oversight problem in the inspection process at Empire Airlines and not a systemic issue with ATOS. Additionally, the FAA took corrective action to assure that changes to Empire Airlines' FTM were initiated to assure that the required meteorological training was being conducted by the operator.

2.5 Survival Aspects

According to dispatch logs, the accident alarm sounded at 0438:12. ARFF personnel who were dispatched to the scene reported that they proceeded on the taxiways with caution because of the ice. The ARFF response vehicles arrived on scene without difficulty at 0442:31, and ARFF personnel immediately began fire suppression and contained the fire (with the exception of a few interior cargo fires) within minutes. Thus, the NTSB concludes that the presence of ice on the taxiways between the ARFF station and the accident site minimally increased the response time; however, the emergency response was timely and effective in suppressing the fire.

2.5.1 Lack of Occupant and Hazardous Materials Information Available to First Responders

The first officer opened the cockpit escape hatch without difficulty, but the flight crew decided not to use it for egress because of the fire's proximity. The captain and the first officer opened the forward cargo door without difficulty and exited the airplane. The first officer stated that, before exiting the airplane, the captain attempted to contact the ATCT using the airplane's radio but that the radio was inoperative (the CVR did not capture this attempt). The captain stated that, after exiting the airplane, he called Empire Airlines' dispatch and reported the accident. Both the captain and the first officer then left the scene and ran to the FedEx hangar before the first responders arrived. A FedEx employee subsequently notified the Lubbock Fire Department and EMS personnel when they arrived at LBB that the flight crew was at the FedEx hangar; however, by that time, the ARFF responders were already on scene and looking for survivors.

As a result of the confusion regarding the flight crewmembers' whereabouts, at least two ARFF personnel unnecessarily accessed the airplane to look inside the cockpit and cabin area, and other personnel also unnecessarily interrupted their fire suppression activities to participate in the search. After the arriving fire department personnel conveyed to ARFF personnel that the flight crew was safe, the search was stopped but then was resumed briefly after the ATCT controller relayed information (which was apparently old) that a pilot was walking around on the ramp looking for assistance. In addition, the ARFF personnel were initially unaware of the airplane's HAZMAT cargo. Operators that transport HAZMAT cargo are required to make specific HAZMAT cargo information available during an emergency response, and Empire Airlines' procedures complied with the requirements. However, the requirements do not address situations in which the flight crew may be able to provide more timely, general information in advance of the operator's delivery of the required documents. The ARFF captain indicated that, if they had the information, the ARFF response to the scene would have been similar with the exception that all responding firefighters would have worn full personal protective equipment.

Although the flight crewmembers acted appropriately by ensuring their own safety following the accident, the situation highlights that a lack of information from the flight crew can hinder the response team's ability to safely and most efficiently prioritize their on-scene activities. The NTSB notes that a similar situation occurred on June 28, 2008, during a cargo airplane ground fire in which the flight crew evacuated the airplane and left the scene before first responders arrived, but no information about their safe egress was immediately provided to first responders. In this accident, a firefighter unnecessarily entered the burning wreckage to look for survivors and encountered a dangerous situation in the cockpit, including heavy smoke in which he lost his radio, confined spaces that pulled off some of his equipment, and a "wall of fire" behind the cockpit door. The firefighter indicated that, in hindsight, he should not have entered the cockpit but that he did it because he did not know if anybody was in there and because he thought that he could put the fire out.[147]

The ARFF station was notified of the accident when the ATCT controller lifted the direct-line radio receiver in the tower, resulting in the automatic sounding of a tone in the station. According to procedure, following the tone, the ATCT controller can provide information about the level of the alert, the type of aircraft, the nature of the emergency, the runway to be used, and any other information as time permits. In the case of the accident flight, other than the accident location, the only information about the flight that the ATCT controller could convey was that the airplane was an ATR. ARFF personnel did not know that it was a cargo airplane and that they could expect two or three occupants until they began suppressing the fire and saw the FedEx logo on airplane's tail. Further, as previously discussed, the ARFF responders were initially unaware of the airplane's HAZMAT cargo.

The NTSB concludes that timely information from the flight crew about the safety of the airplane occupants and the presence of on-board HAZMAT cargo would improve the safety and efficiency of the emergency response. Further, the NTSB concludes that, because flight crews cannot always immediately communicate with ATC after an accident, it is important that another

[147] See the Survival Factors Group Chairman's Factual Report in the public docket for *Ground Fire Aboard Cargo Airplane, ABX Air Flight 1611, Boeing 767-200, N799AX, San Francisco, California, June 28, 2008*, Aircraft Accident Summary Report NTSB/AAR-09/04/SUM (Washington, DC: National Transportation Safety Board, 2009). <http://www.ntsb.gov/Dockets/Aviation/DCA08MA076/407654.pdf>.

method be developed to communicate information, such as the number of occupants on board and the presence of hazardous materials, to ARFF personnel upon initial notification of an accident. Therefore, the NTSB recommends that the FAA develop a method to quickly communicate information regarding the number of persons on board and the presence of hazardous materials to emergency responders when airport emergency response or search and rescue is activated.

2.5.2 Inoperative Emergency Response and Mutual Aid Gate

The airport's emergency plan indicated that units that respond from outside of the airport should "respond to Gate 6 and Gate 48 or at a location prescribed by the command post." However, the emergency response unit that arrived at Gate 48 could not access the airport at that location because the gate was inoperative due to ice in its operating mechanism. The remaining response units were able to divert to another gate for airport access, which minimally delayed their response time.

The LBB snow and ice removal plan did not address checking or ensuring the operability of the airport gates. A survey of several other 14 CFR Part 139 airports with operations affected by winter weather revealed that none of the airports' snow and ice operations plans addressed checking or ensuring the operability of emergency response and mutual aid gates. Also, AC 150/5200-30C did not address the issue.

The NTSB notes that airport operations personnel are already required by airport snow and ice removal plans to conduct periodic inspections of the routes used by emergency response vehicles. Therefore, the checking of mutual aid gates for operability could easily be added as an item to be performed during these inspections. Further, following the accident, LBB voluntarily added the checking of mutual aid gates for operability to its snow and ice operations plan. The NTSB concludes that an iced and inoperable mutual aid gate could extend the response time of mutual aid, which could delay the delivery of medical attention to accident survivors and result in further fire damage to property. Therefore, the NTSB recommends that the FAA amend AC 150/5200-30C to include guidance on monitoring and ensuring the operability of emergency response and mutual aid gates during winter operations.

2.6 Airplane Equipment Options

2.6.1 Aircraft Performance Monitoring

ATR developed the APM system, which has been installed on new production ATR 42 and ATR 72 airplanes since November 2005, to enhance a flight crew's ability to detect the effects of severe icing conditions on the airplane. The APM is a condition-specific, low-airspeed alerting system because it is designed to provide specific alerts in icing conditions only (level 2 or 3 icing protection must be engaged or an icing signal must be provided by the icing detector). The APM calculates and compares the airplane's actual performance (with respect to airspeed and drag) with its expected performance, computes the actual minimum icing and severe icing airspeeds, and provides alerts to the flight crew when low airspeed or performance degradation is detected. These alerts prompt the flight crew to perform the specified QRH procedures (depending upon the type of alert) to respond to the effects of icing on the airplane's performance.

Although the APM is intended to help flight crews recognize and respond to performance degradations developed while operating in severe icing encounters, the APM alerts are an important safety enhancement for flights operating even in moderate icing conditions, like the accident flight. For example, had the accident airplane been equipped with an APM, the blue "CRUISE SPEED LOW" annunciator lights would have illuminated about 70 seconds before the flap anomaly, and the amber "DEGRADED PERF" annunciator lights and a single chime would have activated about 40 seconds before the flap anomaly. An APM would not have provided any further alerts after the flight crew selected flap extension because the system requires a flaps-up configuration.

According to ATR, the appropriate flight crew response to the "DEGRADED PERF" alert includes maintaining red-bug airspeed plus 10 kts. The NTSB notes that, although the accident flight's hazardous low-airspeed situation resulted from the flight crew's inadequate airspeed management rather than the performance degradation from the moderate icing encounter, had the accident airplane been equipped with an APM, the APM would have provided icing-related alerts that may have alerted the flight crew of the need to be more attentive to airspeed management during the approach. Thus, the NTSB concludes that the APM system is a valuable low-airspeed alerting tool that can enhance safety in all icing conditions.

APM retrofits for older ATR 42 (like the accident airplane) and ATR 72 airplanes have been available since June 2006, and, effective August 24, 2009, EASA required that all EASA-participating operators (operators in the European Community, its Member States, and the European third countries) of ATR 42 and 72 airplanes not originally equipped with the APM system retrofit their airplanes with the system within 72 months or by the second "C" check, whichever occurs first. The FAA did not take similar action. As a result, APM system retrofits are optional for U.S. operators.

In a January 14, 2011, letter responding to a query from NTSB investigators, the FAA stated that its decision not to require APM retrofits for U.S. operators was based, in part, on its finding that, in five of the ten icing-related events that were cited by EASA when mandating the APM, the flight crewmembers were aware they were in severe icing conditions but did not follow mandatory operating limitations. Therefore, the FAA reasoned that although the APM would have provided alerts in four of these five cases, "it cannot be determined if the flight crew would have acted any differently in response to an APM alert than they did to observing the severe icing cues." The NTSB notes that, in times of high workload, an alert even a few seconds earlier that an ice accretion has crossed the line from "normal" to severe would be beneficial because it would allow the flight crew to take immediate action. Because the APM warns of performance degradations when they begin to occur, even if the autopilot is on and the crew is unable to detect degradation in performance, the APM can provide warnings to flight crews that a hazardous low-airspeed situation is developing well before the icing conditions become severe. The NTSB does not concur with the FAA's position that APMs would not help flight crews in icing conditions and believes that the FAA should reexamine its decision not to require APM retrofits for U.S. operators. Therefore, the NTSB recommends that the FAA require all operators of ATR 42- and ATR 72-series airplanes to retrofit the airplanes with an APM system if they are not already so equipped.

2.6.2 Flap Malfunction or Asymmetry Light

During the accident flight, the flap asymmetry was not quickly or accurately identified by either flight crewmember, despite several available cues, including the cockpit flap position indicator, the exterior wing flap position fairings, the left control wheel input by the autopilot (and the resulting 5° heading change of the airplane), the airplane's failure to decelerate as expected, and the "RETRIM ROLL L WING DN" and "AILERON MISTRIM" messages on the ADU. Although it is possible that the flight crewmembers did not detect all of the cues (both the captain and the first officer stated that they did not see any messages on the ADU), the cues they did observe were not rapidly interpreted as indicative of a flap problem.

The NTSB notes that the ATR 42-320 (the accident airplane model) is one of only a few models of transport-category airplanes certificated without a flap malfunction light (either a light to indicate any flap malfunction or a specific asymmetry light) in the cockpit (other models are the ATR 42-200 and -300 and the Cessna 500, 550, 553, 560, and 560XL airplanes). Certification testing for these airplanes demonstrated that a cockpit light was not required because a flap malfunction (including an asymmetry) did not constitute an unsafe flight condition.

If the accident airplane had been equipped with a flap malfunction light in the cockpit, the light would have illuminated amber in response to the flap asymmetry and would have provided the flight crew with an immediate, definitive indication of a flap problem. The NTSB concludes that, if the accident airplane had been equipped with a flap asymmetry light, as many other ATR 42- and ATR 72-series airplanes are equipped, the illumination of that light would likely have made the nature of the malfunction more salient to the flight crew and may have triggered a more appropriate crew response. Therefore, the NTSB recommends that the FAA require that all ATR 42-series airplanes be equipped with a flap asymmetry annunciator light if they are not already so equipped.

2.6.3 Ice Evidence Probe

The accident airplane was not equipped with an IEP, which was an optional installation for ATR airplanes that were not originally equipped with this device. Although an IEP provides a surface upon which ice accumulation can be visually detected, the propeller spinners serve this function for airplanes that are not equipped with an IEP, and the first officer indicated that she observed ice on the spinners. Also, the AAS alerted the flight crew in a timely manner to apply the procedures and checklists required when flying in icing conditions. Thus, the NTSB concludes that the absence of an IEP, which was an optional installation, did not hinder the flight crew's ability to detect airframe ice accretion.

2.7 Simulator Training for Icing Encounters

During the accident flight, both the flap asymmetry and the airframe ice accretion adversely affected the airplane's performance. Aerodynamic coefficient extraction indicated that drag beyond the level expected for an uncontaminated airframe was present during cruise and the final minutes of the flight. ATR estimated that, by the time that the flap asymmetry occurred, a drag increase (due to ice) corresponding with about 23 percent of total power was present. The EFS could not reproduce the accident airplane's drag levels from ice accretion without introducing unrealistic lift and pitch, roll, and yaw moments; therefore, the full extent of the performance degradations could not be determined or duplicated in the EFS. No requirements exist for simulators to be qualified with validated data, such as flight test and FDR data, for the effects of airframe ice accumulation.

In this accident, the airplane's stall warning system operated as designed and warned the flight crew of the airplane's proximity to the stall. However, other accidents and incidents have occurred in which airframe ice accumulation has resulted in airplanes entering an aerodynamic stall without any warning to the flight crews. For example, on January 2, 2006, a Saab SF340 operated by American Eagle Airlines, Inc., encountered icing conditions during the en-route climb and departed controlled flight at an altitude of about 11,500 feet msl, losing about 5,000 feet of altitude before the pilots recovered control of the airplane.[148] The flight crew was using the autopilot in vertical speed mode at the time that airplane control was lost, and information from the FDR showed that the upset began before the stall warning activated.

The performance degradations associated with airframe ice accretion can result in an aircraft slowing down much faster than normal and stalling at a much higher airspeed than normal. Both conditions require pilot vigilance to recognize and react to the performance degradations; however, both the American Eagle incident flight crew and this accident flight crew failed to properly monitor and manage the airplanes' airspeed. Although flight crews are trained to use higher airspeeds during icing conditions, the effects of performance degradations resulting from ice accretion are not realistically duplicated in a simulator.

The NTSB concludes that simulator-based training scenarios that realistically reflect aircraft performance degradations that result from airframe ice accretion can better prepare flight crews to effectively respond to decaying airspeed situations and other situations that can occur during in-flight icing encounters. Therefore, the NTSB recommends that the FAA define and codify minimum simulator model fidelity requirements for aerodynamic degradations resulting from airframe ice accumulation. These requirements should be consistent with performance degradations that the NTSB and other agencies have extracted during the investigations of icing accidents and incidents.

The NTSB further recommends that the FAA, once the simulator model fidelity requirements requested in Safety Recommendation A-11-46 are implemented, require that flight crews of all aircraft certificated for flight in icing conditions be trained in flight training simulators that meet these fidelity requirements. Such simulation training should emphasize the

[148] The report for this incident, NTSB case number LAX06IA076, is available online at <http://www.ntsb.gov/aviationquery/index.aspx>.

following: (1) cues for recognizing changes in the aircraft’s flight characteristics as airframe icing develops; (2) procedures for monitoring and maintaining appropriate airspeeds in icing conditions, including the use of icing airspeed reference indices; and (3) procedures for responding to decaying airspeed situations, stall protection system activation, and early stalls that can occur without stall protection system activation.

3. Conclusions

3.1 Findings

1. The captain and the first officer were certificated in accordance with Federal regulations and were current and qualified in accordance with Empire Airlines' training requirements. The investigation found no evidence that the pilots' performance was affected by any behavioral or medical condition, or by the use of alcohol or drugs.

2. The airplane was loaded within weight and center of gravity limits and was maintained in accordance with 14 *Code of Federal Regulations* Part 121.

3. The investigation found no evidence that indicated any mechanical anomaly with the engines, and flight data recorder data indicated that the engines' performance was consistent with normal operations.

4. Performance data indicated that, when the flight crew commanded 15° flaps, a flap asymmetry occurred with the left flaps extending 8° to 10° and the right flaps not extending. The data further indicated that the flaps returned to a symmetric state (about 4.5°) about 25 seconds before ground impact.

5. Because of the extent of the impact and postaccident fire damage to the right flaps and flap actuators, the reason for the airplane's flap asymmetry could not be determined.

6. The airplane was controllable with the flap asymmetry and airframe ice contamination and could have been maneuvered and landed safely if the appropriate airspeed had been maintained.

7. The captain's failure to immediately respond to the aural stall warning, the stick shaker, and the terrain awareness and warning system warning resulted in his inability to arrest the airplane's descent and avoid impact with the ground.

8. The captain was adequately trained on how to respond to flap anomalies, and the captain's statement that the airplane had "no flaps" indicates that he had sufficient information to recognize that he should immediately perform a go-around maneuver and apply the appropriate procedure from the quick reference handbook that applied to all flap problems.

9. Although the captain indicated that he was concerned about the icing conditions, the presence of airframe ice accretion within the capabilities of the airplane's systems does not negate the importance of adhering to standard operating procedures and performing a go-around maneuver to respond to the multiple cues associated with an unstabilized approach including excessive deviation from the glidepath, sink rate greater than 1,000 feet per minute, and airspeed less than the required approach speed.

10. Had the captain complied with standard operating procedures in response to the flap anomaly, unstabilized approach, stick shaker, and terrain awareness and warning system warning and initiated a go-around maneuver, the accident likely would not have occurred.

11. The first officer's failure to maintain airspeed while acting as the pilot flying likely resulted from being distracted by the flap anomaly, the captain's actions in response to it, and the control force inputs needed to maintain aircraft control.

12. The captain's failure to call out the first officer's airspeed deviations resulted directly from his preoccupation with performing an inappropriate, nonstandard procedure in response to the flap anomaly.

13. Although some of the airspeed bugs (including the internal bug) were not set to the appropriate approach airspeeds and were not reset following recognition of the flap anomaly, the flight crew had a sufficient reference to maintain the minimum safe airspeed because the airspeed for a no-flap approach in icing conditions was correctly briefed as 143 knots, and the red airspeed bugs were set near that value.

14. Reliance upon flight crew vigilance and stall warning systems may be inadequate to prevent hazardous low-airspeed situations, and, had a low-airspeed alerting system been installed on the airplane, it may have directed the flight crew's attention to the decaying airspeed earlier and provided an opportunity to take corrective action before the stall protection system activated.

15. The first officer's failure to assert herself to the captain and initiate a go-around maneuver when she recognized the unstabilized approach likely resulted from the steep authority gradient in the cockpit and the first officer's minimal training on assertiveness; further, the captain's quick dismissal of the first officer's go-around inquiry likely discouraged the first officer from voicing her continued concerns and challenging the captain's decision to continue the unstabilized approach.

16. Role-playing exercises are essential for effective assertiveness training because such exercises provide flight crews with opportunities for targeted practice of specific behaviors and feedback that a lecture-based presentation format lacks.

17. The establishment of best practices for conducting both single and multiple emergency and abnormal situations training needs to include training for the occurrence of these situations at low altitudes because low-altitude scenarios require rapid, accurate assessment of abnormal situations and appropriate prioritization of tasks.

18. Although the risk for fatigue existed at the time of the accident due to the window of circadian low, the first officer took steps to mitigate the effects of fatigue, and her errors during the flight can be explained by her lack of experience in both the airplane and in icing conditions along with the distraction caused by the captain's non-standard response to the flap anomaly.

19. Due to the early morning hour of the accident flight and cumulative sleep debt, it is likely that fatigue degraded the captain's performance.

20. Dispatching and operating an airplane in known icing conditions for which the airplane is not certificated and has not demonstrated the ability to operate safely has the potential to reduce or eliminate safety margins.

21. To most effectively ensure the safety of flight operations in icing conditions, pilots, dispatchers, and flight followers must understand how the dangers of freezing drizzle and freezing rain can affect their airplanes and must understand the differences between ground deicing considerations and in-flight icing operations.

22. The presence of ice on the taxiways between the aircraft rescue and firefighting station and the accident site minimally increased the response time; however, the emergency response was timely and effective in suppressing the fire.

23. Timely information from the flight crew about the safety of the airplane occupants and the presence of on-board hazardous materials cargo would improve the safety and efficiency of the emergency response.

24. Because flight crews cannot always immediately communicate with air traffic control after an accident, it is important that another method be developed to communicate information, such as the number of occupants on board and the presence of hazardous materials, to aircraft rescue and firefighting personnel upon initial notification of an accident.

25. An iced and inoperable mutual aid gate could extend the response time of mutual aid, which could delay the delivery of medical attention to accident survivors and result in further fire damage to property.

26. The aircraft performance monitoring system is a valuable low-airspeed alerting tool that can enhance safety in all icing conditions.

27. If the accident aircraft had been equipped with a flap asymmetry light, as many other ATR 42- and ATR 72-series airplanes are equipped, the illumination of that light would likely have made the nature of the malfunction more salient to the flight crew and may have triggered a more appropriate crew response.

28. The absence of an ice evidence probe, which was an optional installation, did not hinder the flight crew's ability to detect airframe ice accretion.

29. Simulator-based training scenarios that realistically reflect aircraft performance degradations that result from airframe ice accretion can better prepare flight crews to effectively respond to decaying airspeed situations and other situations that can occur during in-flight icing encounters.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the flight crew's failure to monitor and maintain a minimum safe airspeed while executing an instrument approach in icing conditions, which resulted in an aerodynamic stall at low altitude. Contributing to the accident were 1) the flight crew's failure to follow published standard operating procedures in response to a flap anomaly, 2) the captain's decision to continue with the unstabilized approach, 3) the flight crew's poor crew resource management, and 4) fatigue due to the time of day in which the accident occurred and a cumulative sleep debt, which likely impaired the captain's performance.

4. Recommendations

As a result of this investigation, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Require that role-playing or simulator-based exercises that teach first officers to assertively voice their concerns and that teach captains to develop a leadership style that supports first officer assertiveness be included as part of the already required crew resource management training for 14 *Code of Federal Regulations* Part 121, 135, and 91 subpart K pilots. (A-11-39)
>
> Prohibit all 14 *Code of Federal Regulations* Part 121, 135, and 91 subpart K operators of pneumatic deice boot-equipped airplanes from dispatching or deliberately operating these airplanes in known freezing rain or freezing drizzle of any intensity, unless the airplane manufacturer has demonstrated that the airplane model can safely operate in those conditions. (A-11-40)
>
> Review the approved pilot, dispatcher, and flight follower training programs and procedures for all 14 *Code of Federal Regulations* Part 121, 135, and 91 subpart K operators and require revisions to the programs and procedures, as necessary, to include standardized training and aircraft-specific information to educate pilots, dispatchers, and flight followers of the dangers of flight operations in freezing precipitation and of the differences between ground deicing considerations and in-flight icing operations. (A-11-41)
>
> Develop a method to quickly communicate information regarding the number of persons on board and the presence of hazardous materials to emergency responders when airport emergency response or search and rescue is activated. (A-11-42)
>
> Amend Advisory Circular 150/5200-30C to include guidance on monitoring and ensuring the operability of emergency response and mutual aid gates during winter operations. (A-11-43)
>
> Require all operators of Avions de Transport Régional Aerospatiale Alenia ATR 42- and ATR 72-series airplanes to retrofit the airplanes with an aircraft performance monitoring system if they are not already so equipped. (A-11-44)
>
> Require all Avions de Transport Régional Aerospatiale Alenia ATR 42-series airplanes to be equipped with a flap asymmetry annunciator light if they are not already so equipped. (A-11-45)
>
> Define and codify minimum simulator model fidelity requirements for aerodynamic degradations resulting from airframe ice accumulation. These requirements should be consistent with performance degradations that the

National Transportation Safety Board and other agencies have extracted during the investigations of icing accidents and incidents. (A-11-46)

Once the simulator model fidelity requirements requested in Safety Recommendation A-11-46 are implemented, require that flight crews of all aircraft certificated for flight in icing conditions be trained in flight training simulators that meet these fidelity requirements. Such simulation training should emphasize the following: (1) cues for recognizing changes in the aircraft's flight characteristics as airframe icing develops; (2) procedures for monitoring and maintaining appropriate airspeeds in icing conditions, including the use of icing airspeed reference indices; and (3) procedures for responding to decaying airspeed situations, stall protection system activation, and early stalls that can occur without stall protection system activation. (A-11-47)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

DEBORAH A.P. HERSMAN
Chairman

ROBERT L. SUMWALT
Member

CHRISTOPHER A. HART
Vice Chairman

MARK R. ROSEKIND
Member

EARL F. WEENER
Member

Adopted: April 26, 2011

Vice Chairman Hart and Members Rosekind and Weener filed the following statements on May 9, 2011.

Board Member Statements

Vice Chairman Christopher A. Hart, dissenting:

I dissent from this report because (a) it is internally inconsistent, and (b) it concludes, without adequate basis, that fatigue contributed to the accident.

Internal Inconsistency. The report is internally inconsistent because, on one hand, it emphasizes the general rule, and the probable cause asserts, that the captain should have discontinued his approach when it became unstable. On the other hand, it recommends that the FAA should prohibit these types of airplanes "from dispatching or deliberately operating" in precisely the type of icing conditions that it says this captain should have re-entered in his go-around. Either the conditions were flyable and should have been re-entered on a go-around, or the conditions were not flyable and the captain appropriately continued his approach, despite being unstable, but not both.[1] I believe that the evidence supports the conclusion that the conditions were flyable and the captain should have gone around.

More specifically, the evidence indicates that the icing conditions encountered during the approach were well within the capability of the airplane and the crew. The crew had appropriately engaged the necessary ice protection systems, they never expressed any concern about icing, and the airplane had plenty of performance despite the icing. Thus, instead of being an icing accident, this was an accident involving an unstable approach that resulted from untimely and excessive corrections, along with poor CRM, during an instrument approach, and there is no basis in the report for concluding that icing was in any way causal or even contributory to this accident.

With a few small exceptions, the flight crew appeared to be working well together and was generally "ahead of the curve" until they began to descend when the autopilot intercepted the glide slope. Because the copilot (who was the pilot flying) did not reduce the power as their descent began, the airplane began to accelerate. Her response to the acceleration was to reduce power very substantially, essentially to flight idle. Making large corrections during an instrument approach is not good practice because large corrections usually necessitate subsequent large corrections in the opposite direction, which, as occurred here, can easily lead to an unstable approach. About fifteen seconds after the autopilot intercepted the glide slope and they began descending, and about ten seconds after she substantially reduced the power, something happened – the investigation apparently was not able to determine with certainty what – that caused the copilot to ask, at 0435:03, "what the heck is going on?" Her question may have been prompted by the airplane's reaction(s) to their effort to extend the flaps because, one second later, the captain responded, "You know what? We have no flaps."

Consequently, as they were rapidly decelerating during their descent along the glide slope, her inquiry and the captain's response about the flaps caused both pilots to divert their

[1] The recommended prohibition against "dispatching" into icing conditions is proactive and appropriate, and does not create an inconsistency. The recommended prohibition against "deliberately operating" in icing conditions, however, flies in the face of asserting that the captain should have aborted his approach and re-entered the prohibited icing conditions.

attention to the flap problem. The captain, as pilot monitoring, appropriately began to trouble shoot, but inappropriately began looking at circuit breakers rather than the flap malfunction checklist. The copilot, however, was also distracted by the flap problem, which diverted her attention away from their decreasing airspeed until it decreased enough to activate the stick shaker and disconnect the autopilot. The copilot's diversion of her attention was contrary to good CRM practice that in the event of a malfunction, one pilot should explore the malfunction, preferably starting with the checklist where appropriate, while the other pilot flies the airplane. After the autopilot disconnected, the approach became unstable, they did not maintain adequate airspeed, even after the stick shaker activated, and the airplane stalled and crashed.

Hence, this accident actually began with the copilot's failure to reduce power when they intercepted the glide slope, followed by her excessive power reduction in response to the resulting acceleration, followed by the distraction caused by the flap problem that diverted her attention – until the first stick shaker event – from the need to restore adequate power to prevent further loss of speed. Because none of the events in this causal chain related to or were caused by icing, this is not an icing accident, and there is no basis from this accident for any recommendations regarding icing.

The higher stall speed due to icing does not undercut my conclusion that this is not an icing accident. The copilot's substantial power reduction caused an initial deceleration of about 2 knots per second, and I am not convinced, for two reasons, that the few additional seconds it would have taken for them to decelerate to a lower (non-iced) stall speed might have produced a different result. First, I see no reason to believe that those extra few seconds would have been enough to cause them to return their attention – before the stall – to the need to arrest their rapid speed decrease. Second, given their lack of appropriate response – not one, not two, but three times – to the stick shaker, I see no basis for concluding that that those extra seconds would have altered their non-response to the stick shaker.

Consequently, I do not believe that this was an icing accident, and

- The fact that they were in icing conditions is not relevant to, and should not be in, the probable cause;
- The recommendations relating to in-flight icing, irrespective of whether they are good ideas, are not supported by this accident; and
- Because Recommendation No. 2 asks the FAA to prohibit operation in the types of icing conditions that were present in this accident, the probable cause should not assert that the captain should have discontinued his approach and ascended back into those icing conditions.

Fatigue. The probable cause concludes that fatigue "likely impaired the captain's performance." Even if the crew had been fatigued, which they probably were to some extent, I do not see any basis in the report for concluding that fatigue resulted in impairment sufficient to cause or contribute to this accident.

There are several aspects about fatigue that necessitate extreme caution before including it as part of the probable cause. To name a few, fatigue:

- Is not either "on" or "off," but can range from none, to extreme, to anywhere in between;
- Can be quite variant from day to day, and can be present one day, enough to cause problems, but not be present to that extent the next day; and it can even be quite variant in the course of a single flight, depending upon the duration of the flight and events during the flight;
- Is very widespread – at any point in time, a large percentage of the population is probably suffering from fatigue to some extent;
- Is multidimensional – it is usually referred to in relation to sleep deficit, but it is also affected by diet, exercise, smoking, alcohol use, age, and other factors, and the impacts and interrelationships among and between those factors are often not well understood;
- Is not directly measurable – it can be ascertained only indirectly, on the basis of actions and behavior;
- Has effects that can arguably be counteracted by processes that are designed to reduce the need to analyze and think, such as standard operating procedures and checklists;
- May be significantly mitigated, at least temporarily to some extent, by an adrenalin rush in a life-threatening situation; and
- May be overwhelmed by the effects of a life-threatening situation.

Given all of these characteristics and uncertainties, caution is warranted regarding the inclusion of fatigue as part of probable cause because, among other reasons, the incomplete understanding of, and inability to measure, fatigue and its effects make it very difficult to conclude that fatigue is causative; and given how widespread fatigue is, query how much our inclusion of it in the probable cause can help us achieve our ultimate objective, which is the issuance of safety-improving recommendations.

In this accident, there is probably ample basis for concluding, based upon sleep alone, that both crewmembers were fatigued to some extent. Less ascertainable, however, is whether their performance was degraded by fatigue enough to be causal or contributory to the accident. As noted above, the flight crew appeared to be working well together and was generally "ahead of the curve," with a few small exceptions, until the autopilot intercepted the glide slope and they neglected to reduce power when they began their descent. Their satisfactory behavior during most of the flight could support the conclusion that their fatigue was not enough to impair their performance, at least in the earlier stages of the flight. Another possible conclusion, however, is that even if their fatigue were sufficient to impair their performance, their use of standard operating procedures and checklists earlier in the flight may have masked the impairment effects. Yet a third possible conclusion is that, even if fatigue did not measurably impair their performance earlier in the flight, it degraded their performance later in the flight enough to be causal or contributory. These varying and not necessarily consistent conclusions that can be drawn from the evidence demonstrate the difficulty of labeling fatigue as causal to performance impairment.

Another complication derives from the fact that this was a life-threatening experience for the crew. We can probably conclude with some confidence that the crew in this accident considered their situation to be life-threatening, perhaps starting with her query, "What the heck is going on?" at 0435:03, followed by his response, at 0435:04, "You know what? We have no flaps." Her question and his answer occurred only 84 seconds before the airplane impacted the ground, during about half of which time they were out of the clouds and were able to see the lighted runway and ground rapidly approaching.

At least two possibilities come to mind from the fact that the experience was life-threatening. First, the crew probably experienced an adrenaline rush, and the adrenaline may have reduced the impairing effects of fatigue, at least temporarily, in the critical final seconds before impact. I am not aware of any literature on this issue, but intuitively it seems very possible that adrenaline could, at least temporarily, counteract some of the potentially impairing effects of fatigue. Second, their behavior in the final seconds before impact may have been so overwhelmingly influenced by their knowledge that they were in a life-threatening situation that the effects of fatigue were insignificant by comparison.

Given this extent of uncertainty, I do not believe that we have adequate basis for concluding in the probable cause that fatigue "likely impaired the captain's performance."

Member Mark R. Rosekind, concurring:

This accident has generated a constructive debate among the staff and Board Members on several key issues, one of which is fatigue. Such debates support a thorough analysis and are at the core of the NTSB's mission. I commend the staff and fellow Board Members for raising these issues.

This accident involved night shift work, circadian lows, and misconceptions regarding the ability to adjust to overnight operations. As the report adequately sets forth, this accident occurred during the window of circadian low at about 0437. Well-established scientific research demonstrates that this time is associated with severe performance reductions, and increased errors, incidents, and accidents. As a result, accidents involving pilot error that occur within this window of time should be thoroughly examined for fatigue. While mitigation strategies can be employed to somewhat counter the performance impairments caused by fatigue, overnight operations will always be inherently more at risk due to the human body's internal circadian clock.

Scientific research has shown that the circadian clock does not fully adjust to night operations over time without very specific interventions that require ideal conditions and are very difficult to achieve. These targeted interventions require specific manipulation of light/dark exposure and sleep which runs counter to our society.

In this accident, both pilots altered their sleep schedules in an effort to adjust their circadian rhythms to their night flying operations. There was no information that either pilot had received education and training about these interventions or had knowledge of the specific actions required to shift circadian rhythms. The First Officer made a more extensive effort to adjust her schedule and maintained it for a longer period of time. Despite these actions, no information indicated she sufficiently employed mitigation strategies to effectively adjust her circadian clock. For example, there is insufficient information to assess her light exposure or whether she slept continuously during her sleep opportunity periods.

While I voted for and supported the conclusions set forth in the report, this concurring statement is written, in part, to disagree with the conclusion that the First Officer's errors "can be explained by her lack of experience in both the airplane and in icing conditions along with the distraction caused by the captain's nonstandard response to the flap anomaly" (Conclusion 18). The evidence that fatigue contributed to her errors is no less than the evidence suggesting that her lack of experience or the Captain's nonstandard response contributed to the accident.

Finally, this accident exemplifies the increased safety-risks associated with overnight shifts and operations during the window of circadian low (at a minimum between 0300 and 0500) and should guide hours of service regulations, scheduling policies and practices, and safety –sensitive operations affected by circadian factors.

Member Earl F. Weener, concurring in part and dissenting in part:

Generally, I agree with the report and recommendations of Notation 8093B, as presented to the Board on Tuesday, April 26, 2011. However, I cannot support the Probable Cause statement, as adopted by the Board, or conclusion number 19.

As discussed at the Board meeting, I am unconvinced the investigation or final report provides sufficient evidence to conclude that fatigue impaired the captain's performance to the extent it can be considered a cause of this accident, not even as a contributory factor.

I agree the captain may very well have experienced fatigue, and fatigue may have even played a role in his performance. However, based on the evidence provided in this case, and as presented in the final report, the causal connection between fatigue and the actions leading to this accident has not been made.

Probable, as the word implies, means more than simply a possibility. The report initially states that sleep needs vary by individual (p. 66). It then identifies several possibilities to explain the captain's performance, including past behavior and stress, along with fatigue. From this observation the report concludes that the captain was "*likely* experiencing *some* fatigue at the time of the accident," (emphasis added) (p. 67), and that "fatigue *likely* degraded his performance" (emphasis added) (p. 68). However, the report fails to provide an explanation for why the possibility of fatigue is any more likely or probable than the other possibilities initially identified. There is an unaccounted leap from several possibilities to explain the captain's performance to the singular conclusion that fatigue likely degraded the captain's performance to the extent it became a contributing causal factor of the accident. Further, the report fails to explain how "likely experiencing some fatigue" becomes "likely degraded his performance." These conclusions, possibilities at best, do not support a finding of probability.

The immediate sequence of events leading to the accident began when the First Officer (FO) mismanaged thrust at the interception of the glide slope. This was followed by loss of airspeed leading to activation of stick-shaker and the subsequent disconnect of the autopilot. The FO then had difficulty tracking the ILS localizer and glideslope and quickly deviated from the ILS approach path to the point where the Captain asked if he should take over the approach. At that point, the captain took manual control of an airplane that was likely out of trim and at a power setting inconsistent with the intended ILS flight path. The airmanship errors committed by the FO were certainly on the order of those subsequently made by the captain. Yet, staff conclude that only the captain's errors were likely caused by fatigue, while the FO's were not. In my opinion, nothing in the report substantiates this difference.

The report does discuss, in great detail, the FO's actions, which, in turn, substantiates the conclusion that her errors can be explained by lack of experience. However, the same level of detail and analysis is lacking in terms of evaluating the captain's actions. In fact, it is quite a stark comparison. Also, the report cites a number of authoritative studies concerning the effects of fatigue on human performance. However, the correlation of the studies to the crew's performance, is ambiguous. The report even acknowledges that the flight crew's failure to monitor air speed, the identified probable cause of this accident, *could be* consistent with the known effects of fatigue; and at the same time, the report notes, the same error has been made by other crew who were *not fatigued* (p. 68). Again, at best, fatigue is one of several possibilities that could explain the captain's performance.

Further, when questioned on these points during the Board Meeting, staff again stated that fatigue was one of a number of possibilities that could explain the captain's performance, and that indeed, it could also be explained by past behavior. The critical basis staff provided for concluding that fatigue was a likely cause of the behavior, was an analysis derived by using the captain's own judgment that he required 6-8 hours of sleep to "feel rested," and choosing to use the more conservative end of this range, 8 hours, to arrive at a calculation of a sleep debt of 4 hours. However, I point out that in the initial draft of this report, fatigue was not identified as a causal issue in this investigation. In fact, in briefings with staff in preparation for the Board meeting, staff made a point of stating that they did analyze the role of fatigue in this accident and ruled it out as a factor, as demonstrated in the initial report. When questioned at the Board meeting on why this determination changed, staff explained that in the initial analysis they chose to use the lower end of the captain's sleep need range, 6 hours, to conduct the analysis and subsequently determined fatigue did not play a role. Candidly, when the outcome of whether a factor contributed to the cause of an accident is dependent on choosing from within a range, the analysis is inconclusive.

Finally, I note the probable cause statement in the final draft of the report states the probable cause for this accident was the flight crew's failure to monitor and maintain a minimum safe airspeed while executing an instrument approach in icing conditions. I further note the original contributing factors to the accident in the initial draft report were limited to: 1) the flight crew's failure to follow published standard operating procedures in response to a flap anomaly; 2) the captain's decision to continue with the unstabilized approach; and 3) the flight crew's poor crew resource management. All of these factors are supported by observable actions or inactions. They were objectively derived, and not one of them is described as simply "likely" to have occurred.

In sum, the report and probable cause, as initially proposed, provided a rational and substantiated explanation for the cause of the accident. Although fatigue may have played a role in the captain's performance during the accident sequence, the final report does not sufficiently make the case that fatigue played a causal role in the event.

5. Appendixes

Appendix A

Investigation and Hearing

Investigation

The National Transportation Safety Board (NTSB) was notified about the accident on January 27, 2009. Staff from the NTSB arrived on scene that same day and remained there until January 30, 2009, to conduct the field portion of the investigation. No Board Member accompanied the team.

In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the NTSB's counterpart agencies in France and Canada, the Bureau d'Enquêtes et d'Analyses (BEA) and the Transportation Safety Board (TSB), participated in the investigation as the representatives of the State of Design and Manufacture (Airframe and Powerplants, respectively). Avions de Transport Régional (ATR) and the European Aviation Safety Agency (EASA) participated as technical advisors to the BEA. Pratt & Whitney, Canada, participated as a technical advisor to the TSB.

Parties to the investigation were the Federal Aviation Administration (FAA); Empire Airlines, Inc.; and FedEx Corporation.

Public Hearing

A public hearing was held on September 22 and 23, 2009, in Washington, D.C. Chairman Deborah A.P. Hersman presided over the hearing.

The issues presented at the public hearing included flight crew procedures, crew resource management and decision making, the airline's training program for flight in icing conditions, and airplane design modifications to monitor and mitigate the effects of icing on airplane performance. Parties to the public hearing were the FAA, Empire Airlines, and ATR.

Appendix B

Cockpit Voice Recorder Transcript

The following is a transcript of transcript of a Fairchild Model A-100A tape CVR, serial number 59653, installed on an Empire Airlines ATR-42-320 (N902FX), which crashed during landing at Preston Smith International Airport in Lubbock, Texas.

LEGEND

CAM	Cockpit area microphone voice or sound source
HOT	Flight crew audio panel voice or sound source
RDO	Radio transmissions from N902FX
CTR	Radio transmission from Dallas center controller
APR	Radio transmission from the Lubbock approach controller
TWR	Radio transmission from the Lubbock tower controller
OPS	Radio transmission from Lubbock FedEx Operations
TAWS	Terrain Awareness and Warning System sound source
-1	Voice identified as the captain
-2	Voice identified as the first officer
-**?**	Voice unidentified
*****	Unintelligible word
#	Expletive
@	Non-pertinent word
( )	Questionable insertion
[ ]	Editorial insertion

Note 1: Times are expressed in CST.

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

Note 3: Words shown with excess vowels, letters, or drawn out syllables are a phonetic representation of the words as spoken.

Note 4: A non-pertinent word, where noted, refers to a word not directly related to the operation, control or condition of the aircraft.

CVR Quality Rating Scale

The levels of recording quality are characterized by the following traits of the cockpit voice recorder information:

Excellent Quality Virtually all of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate only one or two words that were not intelligible. Any loss in the transcript is usually attributed to simultaneous cockpit/radio transmissions that obscure each other.

Good Quality Most of the crew conversations could be accurately and easily understood. The transcript that was developed may indicate several words or phrases that were not intelligible. Any loss in the transcript can be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscure each other.

Fair Quality The majority of the crew conversations were intelligible. The transcript that was developed may indicate passages where conversations were unintelligible or fragmented. This type of recording is usually caused by cockpit noise that obscures portions of the voice signals or by a minor electrical or mechanical failure of the CVR system that distorts or obscures the audio information.

Poor Quality Extraordinary means had to be used to make some of the crew conversations intelligible. The transcript that was developed may indicate fragmented phrases and conversations and may indicate extensive passages where conversations were missing or unintelligible. This type of recording is usually caused by a combination of a high cockpit noise level with a low voice signal (poor signal-to-noise ratio) or by a mechanical or electrical failure of the CVR system that severely distorts or obscures the audio information.

Unusable Crew conversations may be discerned, but neither ordinary nor extraordinary means made it possible to develop a meaningful transcript of the conversations. This type of recording is usually caused by an almost total mechanical or electrical failure of the CVR system.

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:10:52 **START OF RECORDING** **START OF TRANSCRIPT**			
04:13:04 **HOT**	[sound of click]		
		04:14:08 **CTR**	Empire eighty two eighty four.
		04:14:10 **RDO-1**	go ahead.
		04:14:11 **CTR**	Empire eighty two eighty four they said that just about anything in use except for the uh back course. winds are out of the north. eight two six runways are closed uh but I couldn't get a definite answer out of them.
		04:14:27 **RDO-1**	eight and two six are closed?
		04:14:30 **CTR**	Empire eighty two eighty four that's what he said.
04:14:34 **HOT-2**	huh...so that leaves—.		
		04:14:38 **RDO-1**	pretty much leaves the runway three five left.
04:14:40 **HOT-2**	one seven right.		
		04:14:41 **CTR**	Empire eighty two eighty four roger.
04:14:45 **HOT-2**	yeah.		
04:14:45 **HOT-1**	yeah except for he says the winds are out of the north.		

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:14:48 **HOT-2**	yeah but he said that their back course isn't an option which is the only runway— the only approach for three five.		
04:14:55 **HOT-1**	what's that? oh. that is. oh.		
04:14:59 **HOT-1**	well it looks like one seven left— right is the only thing available then.		
04:15:03 **HOT-2**	that's what it sounded like but he didn't really sound like he uh knew all that much either. [sound of laughter]		
04:15:08 **HOT-1**	yeah.		
04:15:13 **HOT-1**	two ninteen it looks like for the—.		
04:15:17 **HOT-2**	for POLLO.		
04:16:28 **HOT-2**	aw crap.		
04:16:29 **HOT-1**	what?		
04:16:30 **HOT-2**	I uh screwed up. I always do that...RNAV NAV.		
04:18:10 **HOT-2**	alright I guess we can go ahead and start down.		
04:18:12 **HOT-1**	alright.		
		04:18:17 **RDO-1**	Empire eighty two eighty four is vacating uh one four thousand for eight thousand.

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
		04:18:22 **CTR**	Empire eighty two eighty four roger.
04:18:43 **HOT-2**	alright so descent checklist.		
04:18:46 **HOT-1**	yup. comin' right up.		
04:18:52 **HOT-1**	uh descent...uh anti-ice is on level three. altimeters three zero one three on the left.		
04:19:00 **HOT-2**	on right.		
04:19:00 **HOT-1**	CCAS is clear. belts and harnesses?		
04:19:04 **HOT-2**	on right.		
04:19:05 **HOT-1**	on the left. descent check complete. approach check. landing lights are on uh cabin altitude is set and looks like it's descending nicely over there. flight instruments and radios?		
04:19:20 **HOT-2**	so you're gonna do this?		
04:19:22 **HOT-1**	want me to do it?		
04:19:23 **HOT-2**	sure.		
04:19:24 **HOT-1**	alright. be mine the ILS we'll get vectors over to it and it's gonna beeee the thirty three card. one oh six is the icing speed...one oh six one twelve...uh twenty three and forty three.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:19:51 **HOT-1**	in the event of a miss it'll be uh climb to thirty seven and a right turn to five hundred feet via the Lubbock one fourteen radial to HYDRO intersection and hold annnd that looks like a parallel entry.		
04:20:17 **HOT-2**	sounds good to me.		
04:20:21 **HOT-1**	climb to thirty seven and a left turn to five out to one fourteen. alright very good. uh questions comments?		
04:20:28 **HOT-2**	acceleration altitude?		
04:20:31 **HOT-1**	uhh.		
04:20:33 **HOT-2**	one seven— where are we? right will be thirty eight eighty.		
04:20:38 **HOT-1**	what is it?		
04:20:39 **HOT-2**	thirty eight eighty.		
04:20:39 **HOT-1**	thirty eight eighty. okay very good.		
04:21:02 **HOT-2**	[sound similar to yawning]		
04:21:19 **HOT-1**	and uh descent approach check is complete.		
04:21:24 **HOT-2**	roger.		
		04:22:06 **CTR**	Empire eighty two eighty four contact Lubbock Approach one one niner point two.

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		04:22:11 **RDO-1**	ninteen two Empire eighty two eighty four good morning.
04:22:16 **HOT**	[sound similar to frequency change tone]		
		04:22:19 **RDO-1**	morning Lubbock Empire eighty two eighty four is out of one zero thousand for eight thousand.
		04:22:25 **APP**	Empire eighty two eighty four Lubbock Approach. [sound of tone]
04:22:29 **HOT-1**	yup. he needs to answer that phone.		
		04:22:32 **APP**	Empire eighty two eighty four Lubbock Approach descend at pilot's discretion maintain six thousand. I haven't had any icing reports. special weather observation at uh one zero zero eight Zulu. wind three five zero at one zero visibility two. light freezing drizzle mist. ceiling five hundred overcast. temperature minus eight dewpoint minus niner. altimeter three zero one two. advise uh braking action advisories are in effect. advise what approach you'd want. runway eight two six is closed.
		04:23:05 **RDO-1**	well that pretty much uh leaves us with one seven right sir.
		04:23:14 **APP**	Empire eighty two eighty four expect ILS runway one seven right.
		04:23:17 **RDO-1**	roger that.
04:23:19 **HOT-1**	uh—.		
04:23:19 **HOT-2**	right.		
04:23:21 **HOT-1**	two miles five hundred feet.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:23:22 **HOT-2**	yeah I can do it then.		
04:23:23 **HOT-1**	yup all yours.		
04:23:24 **HOT-2**	cool.		
04:23:33 **HOT-2**	uh uh did you call—.		
		04:23:33 **APP**	Empire eighty two eighty four mu readings for runway three five left were twenty four twenty five twenty three.
		04:23:40 **RDO-1**	roger.
04:23:48 **HOT-2**	what was that he just said?		
04:23:50 **HOT-1**	RVR?		
04:23:51 **HOT-2**	oh RVR.		
04:23:51 **HOT-1**	did he say RVR reading?		
04:23:54 **HOT-2**	he said something. I— I didn't catch what he said.		
		04:23:58 **APP**	Empire eighty two eighty four fly heading two niner zero vector for the approach.
		04:24:02 **RDO-1**	two nine zero Empire eighty two eighty four and what was that touchdown zone RVR you said again?

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
		04:24:08 **APP**	well RVR's more than six thousand runway one seven right. and the mu readings for runway three five left touchdown twenty four. midpoint uh twenty five. rollout twenty three.
		04:24:21 **RDO-1**	okay very good. I got you now.
04:24:23 **HOT-2**	what is it? m—.		
04:24:24 **HOT-1**	oh it's the braking action yeah.		
04:24:25 **HOT-2**	oh braking action.		
04:24:27 **HOT-2**	I got ya. um.		
04:24:30 **HOT-1**	yeah when we get down there just don't do anything like— just keep it going down the center line of the runway. and don't be touching any brakes and make sure that we get two low pitch stops.		
04:24:39 **HOT-2**	okay.		
04:24:40 **HOT-1**	yeah.		
04:24:43 **HOT-2**	did you call ops yet?		
04:24:45 **HOT-1**	no I didn't. uh they're on thirty one ninety two?		
04:24:49 **HOT-2**	yeah.		
04:24:51 **HOT-2**	that's the normal one isn't it? yeah that's it.		

INTRA-AIRCRAFT COMMUNICATION TIME and SOURCE	CONTENT	AIR-GROUND COMMUNICATION TIME and SOURCE	CONTENT
04:24:53 **HOT-1**	yeah.		
		04:24:57 **RDO-1**	ops eighty two eighty four is like fifteen minutes out.
		04:25:13 **RDO-1**	Lubbock ops eighty two eighty four.
		04:25:17 **OPS**	go ahead eighty two eighty four this is Lubbock.
04:25:17 **HOT**	[sound similar to altitude alert]		
		04:25:19 **RDO-1**	yup uh we're like fifteen minutes out.
		04:25:22 **OPS**	copy that uh eighty two eighty four. we didn't think you guys were comin' in. uh do you know if you 'll be able to depart?
		04:25:29 **RDO-1**	okay uh part of that is broken and unreadable. say again.
		04:25:34 **OPS**	I said we didn't think you guys were coming in this morning. you know if uh you guys are gonna be able to depart?
		04:25:40 **RDO-1**	you got deicing right?
		04:25:43 **OPS**	yeah ten four.
		04:25:44 **RDO-1**	well we don't know yet. we're gonna have to talk about it when we get on the ground.
		04:25:49 **OPS**	okey doke well we'll see you guys in about fifteen minutes.

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		04:25:52 **RDO-1**	roger that.
04:25:53 **HOT-1**	good grief.		
04:25:54 **HOT-2**	do they have icing?		
04:25:55 **HOT-1**	well she says oh we didn't know that you guys were coming. I'm thinking doesn't— doesn't AFW— I mean didn't I call back the numbers?		
04:25:58 **HOT-2**	[sound of laughter]		
04:26:03 **HOT-2**	yeah...huh...that's great...does that mean we can just go straight to uh Midland? [sound of laughter]		
04:26:14 **HOT-1**	don't we wish.		
04:26:18 **HOT-1**	oh we didn't know you were coming. oh for Gods sake.		
04:26:23 **HOT-2**	exactly.		
04:26:30 **HOT-1**	let's see since we're on a heading we'll go with this. and one oh nine two.		
04:26:37 **HOT-2**	that's the...Midland VOR. so thirteen—.		
04:26:42 **HOT-1**	it is—.		
04:26:43 **HOT-2**	where are we here?		
04:26:45 **HOT-1**	uh it is one oh nine five.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:26:47 **HOT-2**	one oh nine five for the localizer.		
04:26:51 **HOT-1**	there we go.		
04:26:53 **HOT-2**	one oh nine five set.		
04:26:56 **HOT-1**	and we'll put in—. it is—.		
04:27:01 **HOT-2**	POLLO.		
04:27:02 **HOT-1**	it is I-L-B-B.		
04:27:07 **HOT-2**	cool.		
04:27:26 **HOT-1**	it's like four miles or something. five point five. I'll buy that.		
04:27:34 **HOT-1**	let's see— we're oh we're on heading now right?		
04:27:35 **HOT-2**	we're on heading yeah.		
04:27:40 **HOT-1**	and...what is it uh one seventy two.		
04:27:44 **HOT-2**	and.		
04:28:00 **HOT-2**	very good thank you.		
04:28:01 **HOT-1**	you're welcome.		

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:28:08 **HOT-1**	what was that one burp? was that a big chunk of ice going into one of our quality Pratt & Whitney one hundreds out there?		
04:28:14 **HOT-2**	that's what I'm guessing it was. [sound of laughter]		
04:28:17 **HOT-1**	nice. let's see—.		
04:28:20 **HOT-2**	that was a little strange.		
04:28:21 **HOT-1**	yeah *.		
04:28:51 **HOT-2**	alright.		
04:29:13 **HOT-1**	yeah one of the guys told me one time that he was here in Lubbock and it was snowing.		
04:29:18 **HOT-2**	weird.		
		04:29:35 **APP**	Empire eighty two eighty four dec— descend and maintain five thousand.
		04:29:38 **RDO-1**	five thousand eighty two eighty four.
04:29:43 **HOT-2**	five thousand set.		
04:29:48 **HOT**	[sound similar to altitude alert]		
04:29:51 **HOT-1**	one to go.		

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:29:52 **HOT-2**	one to go.		
04:30:15 **HOT**	[sound similar to master caution single chime]		
04:30:21 **HOT-1**	wow that was a hell of a change.		
04:30:23 **HOT-2**	no kidding.		
		04:30:35 **APP**	Empire eighty two eighty four turn left heading two six zero.
04:30:36 **HOT**	[sound similar to altitude alert]		
		04:30:38 **RDO-1**	two six zero eighty two eighty four.
04:30:41 **HOT-2**	two six zero...ALT star.		
04:30:48 **HOT-1**	two six zero.		
		04:31:25 **APP**	Empire eighty two eighty four turn right heading two eight zero.
		04:31:29 **RDO-1**	two eight zero eighty two eighty four.
		04:31:33 **APP**	wind change between six and five thousand from the south to the north.
04:31:36 **HOT-2**	hah.		
		04:31:37 **RDO-1**	roger.

INTRA-AIRCRAFT COMMUNICATION TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	AIR-GROUND COMMUNICATION TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
		04:31:39 **RDO-1**	yeah the uh the temperature actually uh dropped uh 'bout eight degrees in that amount of time as well.
		04:31:47 **APP**	yeah you were— you had a— at six thousand you had a south wind blowin' about fifteen degrees to the north and er pushing you off that g— off course that much and when at five thousand it went exactly the opposite.
		04:32:01 **RDO-1**	we concur.
04:32:02 **HOT-2**	[sound of laughter]		
04:32:07 **HOT-2**	my goodness.		
		04:32:19 **RDO-1**	when they sent me down here they said that I would uh I'd find things unusual.
		04:32:24 **APP**	that's— that's west Texas weather for sure.
04:32:27 **HOT-2**	[sound of laughter]		
04:32:51 **HOT-2**	can you ID it for me really quick?		
04:32:53 **HOT-1**	yeah.		
04:32:53 **HOT-2**	thanks.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
		04:33:00 **I-LBB**	[sound of I-LBB morse code identifier]
		04:33:04 **APP**	Empire eighty two eighty four turn seven miles from the outer marker. turn left heading two one zero. maintain five thousand until established on the localizer. cleared ILS runway one seven right approach.
		04:33:13 **RDO-1**	five thousand two ten until established and cleared for the ILS Empire eighty two eighty four.
04:33:19 **HOT-1**	you are cleared for the approach and you are identified.		
04:33:21 **HOT-2**	approach...alright thank you.		
		04:33:26 **I-LBB**	[sound of I-LBB morse code identifier]
04:33:33 **HOT-1**	course alive on the left.		
04:33:35 **HOT-2**	LOC star.		
04:33:35 **HOT-1**	and you're ten miles out. we probably better get this thing uh squared away here.		
04:33:39 **HOT-2**	okay.		
04:33:41 **HOT-1**	annnnd there we go.		
04:33:44 **HOT-2**	alright.		
		04:33:52 **APP**	Empire eighty two eighty four contact tower one two zero point five.

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
		04:33:55 **RDO-1**	twenty point five thanks a lot. we'll see you on the way out.
		04:33:58 **APP**	roger.
04:33:59 **HOT**	[sound similar to frequency change tone]		
		04:34:01 **RDO-1**	Empire eighty two eighty four is uh checkin' in nine out on the localizer inbound.
		04:34:06 **TWR**	Empire eighty two eighty four Lubbock Tower runway one seven right clear to land. winds zero one ze ro at eight.
		04:34:11 **RDO-1**	roger clear to land.
04:34:14 **HOT-2**	alright...go.		
04:34:24 **HOT-2**	flaps fifteen gear down landing check.		
04:34:29 **CAM**	[sound similar to landing gear deployment]		
04:34:33 **HOT-1**	alright awww landing check. start selector is continuous relight. power management is in takeoff. icing AOA is on landing gear confirmed three green.		
04:34:43 **HOT-2**	glideslope star.		
04:34:48 **HOT-2**	confirmed.		
04:34:48 **HOT-1**	uh let's see we should have glideslope star.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:34:52 **HOT-2**	*.		
04:34:52 **HOT-1**	very good...and flaps condition levers to go.		
04:34:58 **HOT**	[sound similar to altitude alert]		
04:34:58 **HOT-2**	alright ah dangit.		
04:35:01 **HOT**	[sound of 0.3 second duration whistle increasing frequency from approximately 835 to 1050 Hz]		
04:35:03 **HOT-2**	what the heck is going on?		
04:35:04 **HOT-1**	you know what? we have no flaps.		
04:35:08 **HOT-2**	aw #.		
04:35:09 **HOT-1**	#.		
		04:35:10 **LB**	[sound similar to outer marker]
04:35:15 **CAM**	[sound of click]		
04:35:16 **HOT-1**	uhh.		
04:35:19 **HOT-2**	*.		
04:35:22 **TAWS**	one thousand.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:35:23 **HOT-2**	okay.		
04:35:28 **HOT-1**	what the hell?		
04:35:30 **HOT**	[sound similar to stall warning and stickshaker lasting 1.1 seconds]		
04:35:31 **HOT-2**	aw #.		
04:35:31 **HOT-1**	yeah don't do that.		
04:35:32 **CAM**	[sound similar to stall warning lasting 0.3 seconds]		
04:35:34 **HOT-2**	alright.		
04:35:36 **HOT-1**	just keep flying the airplane. okay.		
04:35:40 **HOT-2**	should I go around?		
04:35:41 **HOT-1**	no.		
		04:35:41 **TWR**	winds zero one zero at eight.
04:35:43 **HOT-1**	keep descending.		
04:35:44 **HOT-2**	we're getting pretty close here. [straining]		
04:35:45 **HOT-1**	what's that? you want me to finish it?		

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:35:47 **HOT-2**	yes please.		
04:35:48 **HOT-1**	okay my airplane.		
04:35:49 **HOT-2**	your controls.		
04:35:50 **HOT-?**	[sound of heavy breathing]		
04:35:52 **HOT-2**	alright you got power.		
04:35:53 **HOT**	[sound similar to altitude alert]		
04:35:58 **TAWS**	five hundred.		
04:36:00 **HOT-1**	aw #.		
04:36:00 **HOT**	[sound similar to stall warning and stickshaker lasting 0.9 seconds]		
04:36:00 **TAWS**	pull up. pull up.		
04:36:02 **HOT-1**	okay.		
04:36:04 **HOT-2**	there's the runway.		
04:36:15 **HOT-2**	alright your—.		
04:36:17 **HOT-1**	max RPM.		

INTRA-AIRCRAFT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME and SOURCE	**CONTENT**	**TIME and SOURCE**	**CONTENT**
04:36:17 **HOT-2**	max RPM.		
04:36:19 **CAM**	[sound similar to RPM increase]		
04:36:19 **HOT**	[sound similar to stall warning and stickshaker lasting 0.5 seconds]		
04:36:20 **HOT**	[sound similar to stall warning and stickshaker lasting 5.4 seconds]		
04:36:22 **HOT-2**	oh #.		
04:36:25 **HOT-1**	#.		
04:36:25 **HOT-2**	#. [straining]		
04:36:26 **CAM**	[sound of beep]		
04:36:27 **CAM**	[sound of impact]		
04:36:28 **CAM**	[sound of grinding and scraping]		
04:36:29 **CAM**	[sound similar to stall warning]		
04:36:32 **CAM**	[sound of continuous repetitive chime continues until end of recording]		
04:36:43 **CAM**	[sound similar to occupants moving around in cockpit]		
04:36:45 **HOT-1**	get out of the airplane. get out of the airplane.		

TIME and SOURCE	INTRA-AIRCRAFT COMMUNICATION CONTENT	TIME and SOURCE	AIR-GROUND COMMUNICATION CONTENT
04:36:48 **CAM**	[sound of scraping stops]		
04:36:52 **CAM-1**	go out the— go out the hatch.		
04:37:10 **CAM-1**	there's a fire on the right hand side. go out the left.		
04:37:16 **CAM-1**	no you know what—.		
04:37:17 **CAM-2**	what.		
04:37:17 **CAM-1**	when you get out can you get out—.		
04:37:25 **CAM**	[sound similar to door opening]		
04:37:27 **CAM-1**	*.		

04:41:35
END OF TRANSCRIPT
END OF RECORDING