Hard Landing, Gear Collapse, Federal Express Flight 647, Boeing MD-10-10F, N364FE, Memphis, Tennessee, December 18, 2003

Micro-summary: **This McDonnell Douglas DC-10-10F experienced a hard landing, followed by landing gear collapse.**

Event Date: **2003-12-18 at 1226 CST**

Investigative Body: **National Transportation Safety Board (NTSB), USA**

Investigative Body's Web Site: **http://www.ntsb.gov/**

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Hard Landing, Gear Collapse
Federal Express Flight 647
Boeing MD-10-10F, N364FE
Memphis, Tennessee
December 18, 2003

Aircraft Accident Report

NTSB/AAR-05/01

PB2005-910401
Notation 7632A

National Transportation Safety Board
Washington, D.C.

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Notation 7632A
Adopted May 17, 2005

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

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Abstract: This report explains the accident involving Federal Express flight 647, a Boeing MD-10-10F, N364FE, which crashed while landing at Memphis International Airport (MEM), Memphis, Tennessee. Safety issues in this report focus on flight crew performance, emergency evacuations, MEM air traffic control and aircraft rescue and firefighting issues, and flight data recorder reliability.

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Abbreviations

AC	advisory circular
ADC	air data computer
AFFF	aqueous film forming foam
AFS	autoflight system
agl	above ground level
AIRMET	airmen's meteorological information
ALPA	Air Line Pilots Association
ARFF	aircraft rescue and firefighting
ASOS	automated surface observation system
ATC	air traffic control
ATCT	air traffic control tower
ATIS	automatic terminal information service
ATP	airline transport pilot
C	Celsius
CAWS	central aural warning system
c.g.	center of gravity
CFR	*Code of Federal Regulations*
CVR	cockpit voice recorder
EOP	enhanced oversight program
FAA	Federal Aviation Administration
FCC	flight control computer
FCIF	flight crew information file
FDR	flight data recorder
FL	flight level
FMS	flight management system

FOM	flight operations manual
fpm	feet per minute
Fps	feet per second
FSB	Flight Standardization Board
ft-lb	foot-pound
Hg	mercury
IND	Indianapolis International Airport
IRS	inertial reference system
ITU	initial, transition, or upgrade training
ILS	instrument landing system
MAC	mean aerodynamic chord
MEM	Memphis International Airport
MFD	Memphis Fire Department
MIT	Massachusetts Institute of Technology
ms	millisecond
MSCAA	Memphis/Shelby County Airport Authority
msl	mean sea level
OAK	Metropolitan Oakland International Airport
POI	principal operations inspector
P/N	part number
PRIA	Pilot Records Improvement Act
PST	Pacific standard time
RMFD	Rural/Metro Fire Department
sm	statute miles
S/N	serial number
WAGS	windshear alert and guidance system
WME	wind measuring equipment

Executive Summary

On December 18, 2003, about 1226 central standard time, Federal Express Corporation (FedEx) flight 647, a Boeing MD-10-10F (MD-10), N364FE, crashed while landing at Memphis International Airport (MEM), Memphis, Tennessee. The right main landing gear collapsed after touchdown on runway 36R, and the airplane veered off the right side of the runway. After the gear collapsed, a fire developed on the right side of the airplane. Of the two flight crewmembers and five nonrevenue FedEx pilots on board the airplane, the first officer and one nonrevenue pilot received minor injuries during the evacuation. The postcrash fire destroyed the airplane's right wing and portions of the right side of the fuselage. Flight 647 departed from Metropolitan Oakland International Airport (OAK), Oakland, California, about 0832 (0632 Pacific standard time) and was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 on an instrument flight rules flight plan.

The National Transportation Safety Board determines that the probable causes of the accident were 1) the first officer's failure to properly apply crosswind landing techniques to align the airplane with the runway centerline and to properly arrest the airplane's descent rate (flare) before the airplane touched down; and 2) the captain's failure to adequately monitor the first officer's performance and command or initiate corrective action during the final approach and landing.

The safety issues in this report focus on flight crew performance, emergency evacuations, MEM air traffic control and aircraft rescue and firefighting issues, and flight data recorder reliability.

1. Factual Information

1.1 History of Flight

On December 18, 2003, about 1226 central standard time,[1] Federal Express Corporation (FedEx) flight 647, a Boeing MD-10-10F (MD-10),[2] N364FE, crashed while landing at Memphis International Airport (MEM), Memphis, Tennessee. The right main landing gear collapsed after touchdown on runway 36R, and the airplane veered off the right side of the runway. After the gear collapsed, a fire developed on the right side of the airplane. Of the two flight crewmembers and five nonrevenue FedEx pilots[3] on board the airplane, the first officer and one nonrevenue pilot received minor injuries during the evacuation. The postcrash fire destroyed the airplane's right wing and portions of the right side of the fuselage. Flight 647 departed from Metropolitan Oakland International Airport (OAK), Oakland, California, about 0832 (0632 Pacific standard time) and was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 on an instrument flight rules flight plan.

The accident occurred on the last day of the flight crew's 4-day, 3-leg trip during which the captain of the flight, a company check airman, was conducting a line check for the first officer.[4] The first leg of the trip departed MEM about 2100 on December 15, 2003, and arrived at Indianapolis International Airport (IND), Indianapolis, Indiana, about 2215 (2315 eastern standard time). The captain was the flying pilot for that leg. The second leg of the trip departed IND about 1431 (1531 eastern standard time) on December 16 and arrived at OAK about 1850 (1650 Pacific standard time). The first officer was the flying pilot for that leg.

The captain and first officer remained in Oakland on December 17, with no flight duties assigned, then reported for duty on December 18 before the accident flight's scheduled departure time of 0810 (0610 Pacific standard time). The airplane's departure to MEM was delayed until 0832 because of a package sorting issue that was later resolved. The first officer was the flying pilot, and the captain performed the nonflying pilot and line check airman duties.

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

[2] An MD-10 is a DC-10 that has been retrofitted with an advanced-technology flight deck. According to Boeing, the retrofit allows for a two-person flight crew (instead of three), weight savings, increased reliability, and commonality with the MD-11 fleet. FedEx received delivery of its first MD-10s on May 9, 2000.

[3] The five off-duty, nonrevenue FedEx flight crewmembers included a DC-10 captain, who occupied the jumpseat in the cockpit, two DC-10 first officers, an MD-11 first officer, and a DC-10 flight engineer who occupied the courier seats located in the cabin directly aft of the cockpit.

[4] FedEx required this line check because the first officer was a flight crewmember involved in an altitude deviation that occurred shortly after departing Stanstead, England, in November 2003. For additional information regarding this incident, see section 1.5.2.

According to postaccident interviews, cockpit voice recorder (CVR)[5] and flight data recorder (FDR) evidence, and air traffic control (ATC) records, the climb and cruise phases of the flight were routine and uneventful. As the airplane approached MEM, the captain and first officer discussed procedures and runway options and planned for the arrival at MEM. About 1145:40, the first officer briefed the captain on arrival and approach procedures for runways 27 (the primary landing runway option) and 36L (the secondary landing runway option). According to the CVR, about 1156:39, the captain stated, "I need to see a stable approach at a thousand feet. If for some reason we're not stable go around…all right?" The first officer responded, "yep no problem there."

The captain obtained the current MEM automatic terminal information service (ATIS) information and, about 1200:34, stated that the winds were out of "three twenty…sixteen gusts to twenty-two, so…it's more favorable to the three sixes." About 1202:08, the first officer stated, "I just think we should start putting out slats about twenty miles on the other side…because I'm…still fairly unfamiliar with Memphis, so I wanna get configured a bit earlier for that." The captain responded, "do what you want," and provided additional information about normal arrival operations, addressing typical stepdown and traffic pattern procedures, altitudes, airspeeds, and the probability of an early turn into MEM. The first officer acknowledged the information and requested the in-range checklist. About 1203:22, the captain stated, "you're driving and you stay focused on that and make me do whatever you need done." The first officer stated, "okay."

About 1204:46, the captain stated, "two ninety is the default descent speed. Which is just fine. That's what's in there." About 1205:22, the captain continued the in-range checklist, confirming altimeter settings with the first officer. About 1205:37, Memphis Air Route Traffic Control Center advised the pilots to contact MEM approach control. About 1206:00, the captain announced that the in-range checklist was complete, then contacted MEM approach control. The MEM approach controller advised the pilots to expect to land on runway 36L and informed them that ATIS information Zulu was current. The approach controller cleared flight 647 to descend to and maintain 8,000 feet mean sea level (msl).[6] The captain acknowledged the clearance and repeated "three six left" to the first officer.

About 1209:12, the captain advised the first officer that the winds were out of "three twenty at sixteen gusts to twenty two. Ten miles [visibility]. It's still saying wind shear." The first officer responded, "goodness." About 1210:46, the captain stated, "I don't see any other TCAS [traffic alert and collision avoidance system] targets…We may be the lead dog coming in here." About 1211:24, the MEM approach controller instructed the pilots to reduce the airplane's airspeed to 210 knots and then descend to and maintain 6,000 feet. Shortly after the captain acknowledged these instructions, the first officer asked him to confirm the clearance, and the captain repeated the instructions. The first officer repeated the airspeed restriction and asked the captain to extend the slats.

[5] The CVR recorded the last 2 hours 58 seconds of cockpit communications before the accident. See appendix B for a partial transcript of the CVR recording.

[6] Unless otherwise indicated, altitudes are reported as msl.

About 1212:11, the captain stated, "there's BOWEN [a navigational intersection]…one seventy five is the heading out of BOWEN." The CVR recorded the first officer as she responded, "oh, thank you." About 1212:42, the captain stated, "FREAZ [a navigational intersection] is out there fourteen miles from touchdown." About 1213:14, the captain stated, "airport's right there," and the first officer responded, "yep."

About 1213:18, the MEM approach controller advised the pilots to contact MEM approach control on a different frequency. About 30 seconds later, the captain contacted MEM approach control on the new frequency and advised the controllers that flight 647 was level at 6,000 feet. About 1214:15, the first officer requested 15° of flaps. About 1214:33, MEM approach control cleared the pilots to descend to and maintain 5,000 feet and turn 10° right. Afterward, the MEM approach controller advised the pilots that they should expect to land on runway 36R instead of 36L, as previously instructed.

About 1215:39, the captain told the first officer, "three six right's in the fix page and it's in the…FMS [flight management system]," and the first officer thanked him. About 1216:11, the MEM approach controller instructed the pilots to reduce the airplane's airspeed to 190 knots, and the captain acknowledged this instruction. The first officer called for the approach checklist about 1218:10, and the captain responded, "approach check. Briefing's complete to three six right. The altimeter is three zero one zero." As the captain finished speaking, the MEM approach controller instructed the pilots to turn left to a heading of 020° and intercept the localizer[7] for runway 36R. The captain acknowledged the instruction, and the pilots continued the approach checklist, completing it about 1218:58.

About 1219:00, the captain stated that the localizer was "alive"[8] and that they were 18 miles from touchdown. About 10 seconds later, the MEM approach controller told the pilots to reduce the airplane's airspeed to 170 knots and cautioned them about possible wake turbulence from an Airbus airplane that was about 6 1/2 miles ahead of the flight 647 airplane. The captain acknowledged the speed reduction and stated that he was looking for the Airbus airplane. About 1219:24, the first officer stated, "flaps twenty two please," and the CVR then recorded the sound of two clicks. About 1219:28, the captain stated, "I got an Airbus right there…and another one out there looks…about level with us." About 20 seconds later, the MEM approach controller cleared flight 647 to descend to and maintain 2,000 feet. About 1220:20, the captain advised the first officer that they had intercepted the localizer, adding, "we're not yet cleared for the approach." The first officer responded, "that's noted."

About 1221:00, the pilots told the MEM approach controller that they saw the airport. The approach controller then stated, "FedEx six forty seven heavy cleared visual

[7] The localizer is the component of an instrument landing system (ILS) that provides lateral course guidance to pilots during approach and landing. When a pilot dials the ILS frequency for a runway into the airplane's navigation equipment, that equipment receives and displays directional guidance from ILS components on the ground, including the localizer and the glideslope (vertical guidance).

[8] Pilots commonly use the term "alive" to indicate the localizer or glideslope needle movement that occurs as the airplane nears the localizer course.

approach runway three six right, maintain a hundred and seventy knots until MAGEE [a navigational intersection] and you can contact tower now." The captain acknowledged the clearance and switched to the MEM air traffic control tower (ATCT) frequency. About 1221:53, the MEM local controller stated, "FedEx six forty seven heavy, Memphis tower, number two following a heavy Airbus two mile final caution wake turbulence runway three six right. Gain and loss of ten [knots] short final runway three six right, cleared to land."

About 1222:31, the captain stated, "how 'bout four extra knots. I don't like to add extra speed, but you know, three or four knots can make a lot of difference…if you're bumpin' around back and forth." The first officer responded, "good enough…let's go with ah landing gear down. Before landing checklist, please…glideslope's alive." The captain responded, "Spoilers are armed. The gear's down…and three green. Flaps are twenty two. Flaps to go." About 1223:38, the first officer requested 35° of flaps, and the captain acknowledged and complied with this request. About 1223:52, the CVR recorded a single central aural warning system (CAWS) "tailwind shear" alert.[9] The captain stated, "okay, it's all right," and the first officer stated, "goodness."

About 1224:27, the CVR recorded the CAWS callout "one thousand" as the airplane descended through 1,000 feet above ground level (agl). The captain then stated, "visual. Stable. We got a nine thousand foot runway…and we land at a hundred and forty six. A pretty good headwind oughta work out okay." About 1224:52, the first officer stated, "autopilot's coming off." About 1225:02, the captain stated, "checklist is complete. You're cleared to land," and the first officer responded, "thanks." Between about 1225:08 and about 1225:52, the CVR recorded the CAWS altitude alerts for 500, 100, 50, 40, 30, 20, and 10 feet agl followed by the sounds of touchdown about 1225:53. About 1225:56, the first officer stated, "wow," and the CVR recorded the sound of increasing background noise, similar to increased engine rpm, and the sound of rumbling that was increasing in volume.

About 14 seconds after touchdown (about 1226:07), the FDR data showed a lateral load factor of about 1.0 G[10] as the right wing suddenly moved about 6° lower. About the same time, the CAWS "landing gear" alert began to sound, which repeated until the end of the recording. About 1226:25, the captain stated, "here we go," and the airplane began to veer off the right side of the runway. As the airplane veered to the right and came to a stop, a fire developed on the right side of the airplane. About 1226:30, the airplane came to rest in the grass on the right side of the runway. The accident occurred during the hours of daylight. The CVR recording ended when the pilots shut down the engines (thus stopping electrical power to the CVR) about 1226:41. For additional information regarding the airplane's performance and motions during the approach and landing, see section 1.16.

[9] During postaccident interviews, the pilots reported that they decided to continue the approach because the windshear alert was brief and they observed no airspeed excursions during the alert. No other windshear alerts were generated during the remainder of the flight. For information regarding FedEx's windshear procedures, see section 1.17.2.3

[10] One G is equivalent to the acceleration caused by the earth's gravity (32.174 feet/second^2).

1.2 Injuries to Persons

Table 1. Injury chart.

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	0	0	0	0	0
Serious	0	0	0	0	0
Minor	1	0	1	0	2
None	1	0	4	0	5
Total	2	0	5	0	7

1.3 Damage to Aircraft

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

1.4 Other Damage

Several runway edge lights on the right side of runway 36R were damaged.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 59, was hired by Flying Tiger Airlines on July 10, 1978, and became a FedEx employee when the two companies merged on August 7, 1989. He holds an airline transport pilot (ATP) certificate with a multiengine land rating and a flight engineer certificate for turbojet-powered airplanes. The captain's ATP certificate indicated type ratings in the Cessna 500 (issued December 21, 1977) and the MD-11 (issued September 21, 1996). The captain completed initial MD-10 differences training on October 24, 2000.[11] The captain's most recent Federal Aviation Administration (FAA)

[11] A pilot with an MD-11 type rating is qualified to fly the MD-10 if that pilot completes the required differences training. Initial MD-10 differences training at FedEx was incorporated in the 3-week, line-oriented flight training curriculum that was conducted after successful completion of the training and flight tests required for an MD-11 type rating. The MD-10 initial differences training consisted of 8 hours per crewmember in the MD-10 simulator, 6 hours of ground school, and 2 hours of computer-based training. For additional information on differences between the MD-11 and MD-10, see section 1.18.1.

first-class airman medical certificate was issued on December 4, 2003, with a restriction that the holder must wear corrective lenses.

The captain estimated that he had flown about 21,000 total flight hours. FedEx records indicated that, at the time of the accident, the captain had accumulated about 2,602 flight hours as an MD-11/-10 flight crewmember, including about 123 hours and 11 landings in the 90 days preceding the accident. On October 12, 2000, the captain received FAA check airman authorization to conduct line checks at FedEx. According to FedEx training records, the captain's most recent recurrent ground training was completed on September 18, 2003; his most recent MD-11/-10 proficiency check was completed on September 19, 2003; and his most recent MD-11/-10 line check was completed on December 8, 2003.[12] FAA records indicated no accident or incident history or enforcement action, and a search of the National Driver Registry database indicated no record of driver's license suspension or revocation.

1.5.1.1 The Captain's 72-Hour History

The captain stated that he felt well rested when he arrived at MEM about 1900 on December 15, 2003, for the flight to IND. He stated that, on December 16, they departed IND about midday and arrived at OAK after dark. He indicated that, on December 17, when no trip segment was scheduled, he spent the day in Oakland and met the first officer and two other FedEx pilots for dinner about 1720 Pacific standard time that evening. The captain stated that he returned to the hotel about 1930 Pacific standard time. According to the captain, he felt well rested when he and the first officer were picked up for duty from their hotel about 0440 Pacific standard time on the morning of December 18.

1.5.2 The First Officer

The first officer, age 44, was hired by FedEx on February 21, 1996, from Mesaba Airlines, where she had been employed as a DeHaviland DHC-8 captain. She holds an ATP certificate (issued March 21, 1991) with a multiengine land rating and a flight engineer certificate for turbojet-powered airplanes. The first officer's ATP certificate indicated type ratings in the DHC-8 (issued September 21, 1992), Fokker F-27 (issued November 11, 1995), and MD-11 (issued October 22, 1998). FedEx records indicated that the first officer completed initial MD-10 differences training on February 10, 2003. The first officer's most recent FAA first-class airman medical certificate was issued on July 25, 2003, with a restriction that the holder must wear corrective lenses.

The first officer estimated that she had flown about 15,000 total flight hours. FedEx records indicated that, at the time of the accident, the first officer had accumulated about 1,918 flight hours as an MD-11/-10 flight crewmember, including about 61 flight hours and 7 landings in the 90 days preceding the accident. Between February 2003 (when she completed the MD-10 differences training) and the accident flight, the first officer

[12] All FedEx flight crewmembers receive flight simulator training every 6 months. In addition, captains receive an annual line check; first officers do not receive an annual line check.

accumulated about 25.6 flight hours and 2 landings in the MD-10.[13] The first officer's most recent recurrent MD-11/-10 line check was completed on April 18, 2001; her most recent MD-11/-10 simulator proficiency check was completed on November 20, 2003; and her most recent ground training was completed on November 28, 2003.

A review of the first officer's employment, flight, and training records revealed that two of her DHC-8 captain proficiency checkrides (on April 7 and 13, 1994, while she was employed by Mesaba Airlines) were unsatisfactory. According to Mesaba Airlines, the check airman who conducted both proficiency checkrides indicated that the unsatisfactory results were because of "generally poor airmanship." As a result of the first officer's unsatisfactory performance during the April 13 checkride, the FAA inspector who observed that checkride required her to be reexamined for her ATP certificate by an FAA check airman under the provisions of 49 CFR, Chapter 447, Section 44609 (currently codified as Section 44709).[14] On May 15, 1994, the first officer satisfactorily completed the reexamination.

According to FedEx training records, the first officer completed DC-10 flight engineer training on April 17, 1996. She began MD-11 first officer transition training on August 31, 1998, and received her MD-11 type rating on October 22, 1998. The records also indicated that, on October 26, 1999, the first officer failed her MD-11 proficiency checkride; deficiencies were noted in the areas of engine-out takeoff, nonprecision approach, and engine fire/failure/restart. The records further indicated that, after additional training, she satisfactorily completed a proficiency checkride on October 29, 1999. The records also indicated that, on October 17, 2001, the first officer failed another MD-11 proficiency checkride; deficiencies were noted in the areas of powerplant failure, nonprecision approach, missed approach procedures,[15] one/two engine-out landing, and command judgment. The records further indicated that, after additional training, she satisfactorily completed a proficiency checkride on October 19, 2001.

As previously mentioned, the captain was conducting a line check of the first officer because an airplane she was piloting in early November 2003 was involved in an altitude deviation. The first officer stated that, when the altitude deviation occurred, ATC had cleared the flight to flight level (FL) 230[16] during the climbout, but she and the captain believed that they heard the ATC controller clear the flight to FL 330. As the airplane neared FL 260, ATC advised the flight to return to FL 230. As a result of this excursion, the first officer and the captain were required to complete a company-mandated requalification simulator proficiency check and a line check. The first officer successfully

[13] The first officer's previous MD-10 landings occurred on April 21, 2003, and December 16, 2003.

[14] Section 44709 authorizes the FAA to reexamine any pilot at any time. The objective of the reexamination is to determine if a pilot is qualified to exercise the privileges of a particular certificate or rating.

[15] Deficiencies noted during a missed approach might include failure to maintain the headings and/or altitudes described in the missed approach procedure. For additional information regarding FedEx's missed approach/go-around policies, see section 1.17.2.1.

[16] Flight level 230 is an altitude of 23,000 feet msl, based on an altimeter setting of 29.92 inches of Mercury (Hg).

completed the requalification simulator proficiency check on November 20, 2003, and her mandatory line check was being conducted when the accident occurred. (Table 2 documents the first officer's checkride failures as an airline employee.)

Table 2. First officer checkride failures.

Checkride failures	Checkride date/result	Retest date/result	Retest date/result
DHC-8 captain proficiency checkride	April 7, 1994/failed, "generally poor airmanship" cited.	April 13, 1994/failed. Reexamination for ATP certificate required by the FAA observer.	May 15, 1994/satisfactorily completed the reexamination for ATP certificate.
MD-11 first officer proficiency checkride	October 26, 1999/failed, deficiencies noted in the areas of engine-out takeoff, nonprecision approach, and engine fire/failure/restart.	October 29, 1999/satisfactorily completed proficiency checkride.	
MD-11 first officer proficiency checkride	October 17, 2001/failed, deficiencies noted in the areas of powerplant failure, nonprecision approach, missed approach procedures, one/two engine-out landing, and command judgment.	October 29, 1999/satisfactorily completed proficiency checkride.	

During postaccident interviews, the check airman who conducted the November 20, 2003 simulator proficiency checkride stated that the first officer had to repeat one of the engine failure scenarios and described her flying as "in the average range." He stated that he counseled the first officer regarding crew resource management and declaring an emergency without first consulting with the captain. The check airman described her performance as average. (This check airman also reported that he had conducted the first officer's proficiency checkride on October 19, 2001. He stated that, at that time, he considered the first officer a below-average pilot and noted that she was very weak in the areas of procedures and judgment.) For additional information about the first officer's flight history, see the Operations Group Chairman's Factual Report in the public docket for this accident.

FAA records indicated no accident or incident history or enforcement action. However, a search of the National Driver Registry database revealed that the first officer's Arizona State driver's license was suspended from November 15, 1998, to February 16, 1999, for a driving under the influence of alcohol conviction. According to FAA records, the first officer reported the suspension of her driver's license to the FAA's Civil Aviation Security Division. In a February 4, 1999, letter, the manager of the FAA's Aeromedical Certification Division advised the first officer, "We have carefully reviewed your letter and your complete medical file, which reveals a previous alcohol-related offense."[17] The

manager indicated that the FAA would review the first officer's ability to hold a medical certificate and asked her to submit additional information, including an evaluation from a substance abuse specialist. In a March 2, 1999, letter, the manager wrote, "I have reviewed the information submitted by you in support of your request for an airman medical certificate. The medical evidence reveals a history of substance abuse (two alcohol-related offenses)…I have determined, however, that you may be granted authorization for special issuance of a first-class airman medical certificate under 14 CFR 67.401. The certificate you hold is valid until the normal date of expiration." The first officer completed the special issuance authorization period that ended on May 31, 2000, with no further alcohol-related offenses and satisfactory first-class medical examinations. The first officer's medical certificate was not revoked during this period.

1.5.2.1 The First Officer's 72-Hour History

The first officer stated that she arrived in Memphis about midday on December 15, 2003, took a nap at the hotel, and felt well rested when she reported for duty at MEM. She indicated that, after arriving at IND, she checked into the hotel and went to bed about 0230. The first officer stated that on December 16, she slept until about 1300 and was picked up for the flight to OAK about 1445. She indicated that she felt well rested for the flight. She stated that she and the captain worked well together during the flight and that he provided positive feedback several times.

According to the first officer, after she checked into the hotel in Oakland, she went to a bookstore and then out for dinner. She stated that she returned to the hotel about 2200 Pacific standard time and went to bed. The first officer stated that, on December 17 (when no trip segment was scheduled), she spent a leisurely day in Oakland and met the captain and two other FedEx pilots for dinner that evening. She stated that, after dinner, she returned to the hotel and went to bed about 2100 Pacific standard time.

The first officer stated that she felt fine when she awoke about 0345 Pacific standard time on the morning of December 18. Although the CVR recorded numerous sounds "similar to throat clearing" and "similar to coughing" on the first officer's channel and a discussion between the captain and the cockpit jumpseat occupant about the first officer's health on the cockpit area microphone (CAM) channel, the first officer stated that she felt fine during the accident flight and was not taking any medication.

1.5.2.2 The First Officer's Landing History

As previously stated, review of FedEx records indicated that the first officer had flown about 61 hours and made 7 landings (6 in the MD-11, 1 in the MD-10) during the 90 days preceding the accident. The Safety Board's review of the weather conditions for landings performed by the first officer between August and December 2003 indicated that she had encountered a variety of wind conditions during that time.[18]

[17] FAA airman medical records showed that the first officer had been previously charged with an alcohol-related traffic offense in 1993 and was later convicted of reckless driving; her driver's license was not suspended or revoked in association with the 1993 offense.

The investigation revealed that, during the 12 months preceding the accident, the first officer had frequently flown as a "reserve first officer," providing relief for assigned flight crewmembers during required en route rest periods. According to several pilots who were interviewed after the accident, "reserve" pilots typically made fewer landings than assigned flight crewmembers.[19]

1.6 Airplane Information

The accident airplane, N364FE, an MD-10-10F series airplane, was equipped with three General Electric CF6-6D engines. According to FedEx records, the accident airplane had about 65,375 total hours of operation at the time of the accident.

According to the dispatch documents for the accident flight, the airplane's takeoff weight was 408,302 pounds, and its takeoff center of gravity (c.g.) was 16.3 percent mean aerodynamic chord (MAC).[20] The airplane's estimated landing weight was 358,450 pounds, including about 110,600 pounds of cargo and about 20,300 pounds of fuel. The dispatch documents indicated that the airplane's maximum landing weight was 375,000 pounds. According to the documents and postaccident examination, no hazardous cargo was on board the airplane.[21]

1.7 Meteorological Information

1.7.1 Weather for Memphis International Airport

MEM is equipped with an automated surface observing system (ASOS),[22] which continuously measures wind speed and direction,[23] visibility, precipitation and obstructions to vision, cloud height and sky cover, temperature, dew point, and altimeter setting. A review of the weather observations revealed that the sustained winds 15 to 20 minutes before and after the accident were consistently from the northwest at 17 to 23 knots. The following conditions were recorded by the ASOS about the time of the accident:

[18] For additional information, see the Operations Group Chairman Factual Report Addendum 2.

[19] Federal regulations require pilots to perform three takeoffs and landings within a 90-day period to maintain currency. FedEx pilots who are unable to maintain landing currency through their normal flight line duties could satisfy the 90-day requirement in the simulator.

[20] According to Boeing, the airplane's takeoff c.g. limits were between 15.4 and 30.3 percent MAC.

[21] For additional information about the airplane's cargo, see section 1.12.3.

[22] The ASOS is located about 1.6 sm northwest of the accident location at an elevation of about 330 feet.

[23] The ASOS station samples wind direction and speed every 5 seconds and records a 2-minute average wind direction and speed every minute. For additional information, see the Meteorology Group Chairman's Factual Report in the public docket for this accident.

> MEM weather at 1225, wind from 320° at 21 knots, with gusts to 26 knots; visibility 10 sm; a broken layer of clouds at 4,500 feet; temperature 11° C [Celsius]; dew point -1° C; altimeter setting 30.09 inches Hg [mercury]; pressure altitude 180 feet; and relative humidity 46 percent. Remarks: peak wind 330° at 26 knots occurred at 1220.
>
> MEM weather at 1230, wind from 310° at 23 knots, with gusts to 28 knots; visibility 10 sm; a broken layer of clouds at 4,500 feet; temperature 10° C; dew point -1° C; altimeter setting 30.09 inches Hg; pressure altitude 180 feet; and relative humidity 46 percent. Remarks: peak wind 320° at 28 knots occurred at 1229; aircraft mishap.

Wind measuring equipment (WME)[24] located at MEM provided additional information about the wind speed and direction on the day of the accident. A WME sensor was located about 1 sm northwest of the accident site and was positioned at 80 feet agl. Data from the sensor indicated numerous oscillations in the sustained wind speed between 1200 and 1245, including several gusts. The sustained wind speed increased from about 14 knots at 1224:53 to about 23 knots at 1226:45. The data showed that between 1200 and 1245, a maximum gust of 29 knots was recorded.

The MEM 1153 ATIS broadcast (identified as ATIS information Zulu) reported that winds were from 320° at 16 knots with gusts to 22 knots, visibility was about 10 sm, clouds were broken at 4,300 feet, temperature was 10° C, dew point was 0° C, and altimeter setting was 30.10 inches Hg. The ATIS also noted that windshear advisories were in effect at MEM. In addition, about 1010, the National Weather Service issued an AIRMET,[25] advising pilots of "occasional moderate turbulence below 8,000 feet due to gusty northerly winds" for an area that included MEM.

FedEx dispatchers provided the pilots with preflight weather information that indicated turbulence below 8,000 feet and strong northerly/northwesterly winds aloft and at the surface.

1.7.2 Massachusetts Institute of Technology/Lincoln Laboratory Study

At the Safety Board's request, the Weather Sensing Group at the Massachusetts Institute of Technology (MIT)/Lincoln Laboratory reviewed data from the MEM terminal Doppler weather radar and integrated terminal weather system terminal winds. On February 2, 2004, Massachusetts Institute of Technology/Lincoln Laboratory staff issued a report that summarized its findings. According to the report, although the winds at MEM were gusting out of the northwest, the data showed no evidence of horizontal windshear or other hazardous conditions near the runway at the time of the accident.[26] The study was

[24] The WME was formerly part of a low level wind shear alert system at MEM.

[25] AIRMET is an abbreviation for airmen's meteorological information. AIRMETs are issued to alert pilots to weather phenomena that are of operational interest and/or are potentially hazardous, including moderate turbulence.

not able to definitively determine the presence or magnitude of small-scale turbulence at or near the surface. The report noted a pattern of buoyancy waves[27] aloft that might have been responsible for the CAWS tail windshear warning recorded by the accident airplane's CVR. However, the report also pointed out that less than 15 knots of windshear was associated with these waves and that this amount of windshear "should not negatively impact the operation of the aircraft."

1.8 Aids to Navigation

No problems with any navigational aids were reported.

1.9 Communications

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

1.10 Airport Information

MEM is located about 3 miles south of Memphis, Tennessee. The official airport elevation is 341 feet. The airport was certificated under 14 CFR Part 139 as an Index D airport.

The airport has four runways: runway 9/27 is an east/west runway located on the northern section of the airport, and runways 18R/36L, 18C/36C, and 18L/36R are three parallel north/south runways that are located on the southern section of the airport. Runway 18L/36R (the accident airplane landed on runway 36R) is 9,000 feet long and 150 feet wide and is located on the east side of the airport. (Figure 1 is a diagram of MEM.) Runway 36R is accessible by numerous taxiways that run perpendicular, parallel, and angular to it.

[26] The Safety Board also derived wind information from recorded FDR data. For additional information, see section 1.16.1.2.

[27] The report described buoyancy waves as parcels of air that oscillate, rising and falling between slightly above the boundary layer to near the surface. Buoyancy waves, which often occur in a gusting wind environment, may have existed from just above the ground to about 4,800 feet agl at the time of the accident.

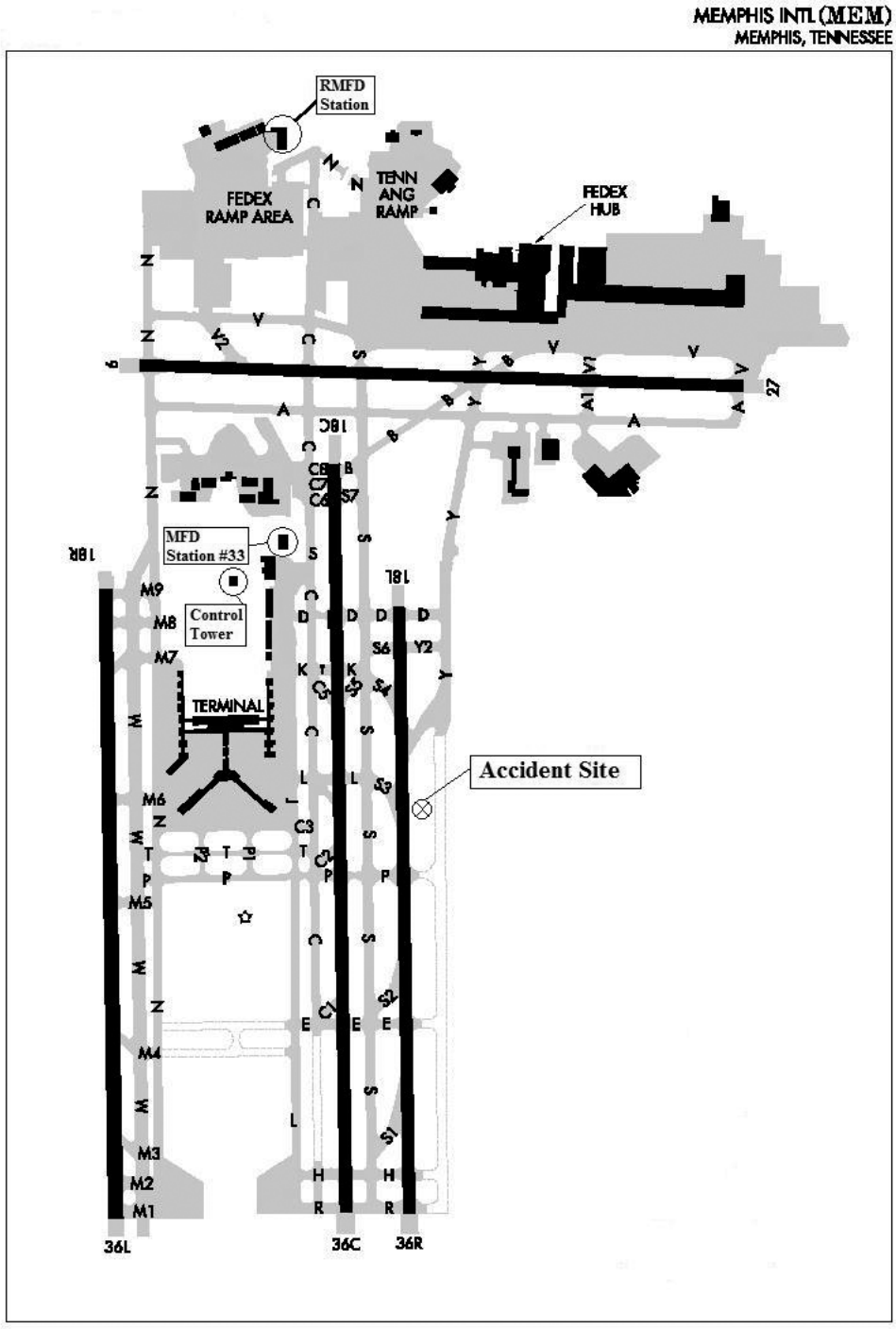

Figure 1. MEM airport diagram.

1.10.1 MEM Aircraft Rescue and Firefighting General Information

The Memphis-Shelby County Airport Authority (MSCAA) operates MEM and is responsible for airport operations and establishing and maintaining an emergency plan.

According to a November 1, 2000, letter of agreement between the FAA, City of Memphis Fire Department (MFD), and the airport authority, titled, "Airport Emergency Procedures," airport rescue and firefighting (ARFF) services at MEM are provided by MFD personnel. MFD operates the fire station at MEM (fire station no. 33) in accordance with 14 CFR 139.319. The fire station is located near the ATCT between runways 18R/36L and 18C/36C. The fire station provides ARFF services for the airport 24 hours a day/7 days a week with a staff of 30 firefighters, at least 18 of whom are present at all times. As required for airports certificated under Part 139, the airport authority conducts annual ARFF tabletop exercises and triennial full-scale ARFF drills. MEM records indicated that the most recent tabletop exercise occurred April 8 and 9, 2003, and that the most recent triennial full-scale drill occurred in April 2002.

Three MFD station no. 33 ARFF vehicles responded to the accident site.[28] In addition, two ARFF trucks owned and operated by the Rural/Metro Fire Department (RMFD) responded to the accident.[29] RMFD is contracted by FedEx to provide emergency medical and fire response services for its operations and is based on the FedEx ramp on the north side of the airport. It is staffed 24 hours a day/7 days a week and often participates in MEM airport emergency drills and exercises. The letter of agreement between the FAA, MSCAA, and MFD indicated that if an alert II and/or III[30] emergency occurred, the crash telephone at RMFD would automatically activate; however, there was no formal agreement between the airport authority, RMFD, and MFD that described RMFD responsibilities and involvement in emergency situations.

During postaccident interviews, MFD and RMFD personnel indicated that the two fire companies had a good working relationship and conducted periodic coordination exercises.[31] They stated that RMFD had an "unwritten" agreement with MFD to assist MFD with all alert II and III ARFF activities (not only those involving FedEx airplanes). Further, RMFD personnel have observed MEM annual tabletop training exercises and substituted for MFD when MFD personnel were involved in off-airport exercises during the triennial full-scale drills in April 2002.

[28] Each of the three MFD vehicles was capable of holding 3,000 gallons of water, 420 gallons of aqueous film forming foam (AFFF), and 500 pounds of Purple K (a dry chemical agent commonly used by ARFF).

[29] One of the RMFD vehicles was capable of holding 97 gallons of water, 3 gallons of foam, and 500 pounds of Purple K. The other RMFD vehicle was capable of holding 1,500 gallons of water and 210 gallons of AFFF. For a complete list of responding vehicles, see the Survival Factors Group Chairman factual report in the docket for this accident.

[30] According to MSCAA, an alert II occurs when an airplane is experiencing difficulty and a potential emergency situation exists requiring emergency equipment to respond to an appropriate standby position on the airport. An alert III occurs when an aircraft accident has occurred and emergency equipment is needed at the scene to commence firefighting or rescue operations. This accident resulted in an alert III.

[31] MFD personnel stated that the periodic coordination exercises conducted with RMFD often involved familiarization with FedEx airplane systems and structures (for example, battery location, auxiliary power unit shutdown procedures, emergency exit door/slide operation, etc.).

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The accident airplane was equipped with an AlliedSignal model 6022 CVR, serial number (S/N) 1656. The CVR did not appear to have any heat or structural damage, and the audio data were successfully downloaded from the solid-state memory. Of the CVR's four channels of audio data, three channels (those that recorded information through the radio/intercom audio panels at the captain and first officer positions and the CAM) contained good to excellent quality[32] audio information; the fourth channel (which was not required by Federal regulations) did not contain any useful audio information.

The recording began at 1025:43 and ended at 1226:41 after the pilots shut down the engines. The downloaded audio data were saved in two separate data files: a two-channel recording of the last 2 hours of CVR information and a four-channel recording of the last 30 minutes of CVR information. A partial transcript was prepared of selected excerpts of the 2-hour, 58-second CVR recording (including the last 30 minutes), as shown in appendix B.

1.11.2 Flight Data Recorder

The accident airplane was equipped with a solid-state Honeywell model FDR, S/N 08411 that recorded about 450 parameters of airplane flight information in a digital format using solid-state flash memory. The FDR was recovered in good condition, and about 27 hours of data were successfully downloaded. The recorded parameters included radio altitude; indicated and ground airspeeds; magnetic heading; control column, control wheel, and rudder pedal positions; aileron, elevator, and rudder surface positions; trailing- and leading-edge flap and slat positions on both wings; vertical, lateral, and longitudinal accelerations; pitch and roll attitudes; wind direction and speed; predictive windshear warning and alert; and head and tail windshears.

1.11.2.1 FDR Recording of Aileron Positions

During its investigation, the Safety Board observed that, although the FDR sampled each aileron position four times per second (more frequently than required by 14 CFR 121.344, appendix M), the aileron position data were not being updated from the data source at the rate required by the regulation. The Board's flight data study showed that, as a result of the inadequate update rate, the data for all four ailerons (inboard and outboard on the right and left wings) showed inaccurate repeated values. For example, examination of 5-second spans of plotted aileron data revealed that they contained six sets of data in which a recorded value was repeated three times, followed by one set of data in which a recorded value was repeated twice. According to the Board's study, this reflects

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

an approximate update rate of once per 700 milliseconds (ms) instead of the once-per-500-ms rate that is required by Federal regulation.

The Safety Board has found similar problems regarding FDR data update rates with other airplane FDR systems and, as a result, issued two safety recommendations to the FAA on May 16, 2003, recommending the following:

> Require that all Embraer 145, Embraer 135, Canadair CL-600 RJ, Canadair Challenger CL-600, and Fairchild Dornier 328-300 airplanes be modified with a digital flight data recorder system that meets the sampling rate, range, and accuracy requirements specified in 14 *Code of Federal Regulations* 121.344, Appendix M. (A-03-015)

> Survey all aircraft required by Federal regulation to have a flight data recorder to ensure that the data recorded meets the rate, range, and accuracy requirements specified in 14 *Code of Federal Regulations* 121.344, Appendix M. (A-03-016)

In an August 11, 2003, letter, the FAA indicated that it was working with the airplane manufacturers and airworthiness authorities involved to address the issues discussed in Safety Recommendation A-03-015 and that it would take appropriate action to correct any deficiencies. With regard to Safety Recommendation A-03-016, the FAA stated that it would ask all airplane manufacturers not addressed in Safety Recommendation A-03-015 to provide FDR design criteria information for obtaining data in accordance with 14 CFR 121.344, Appendix M requirements. Upon review of the design criteria, the FAA would identify necessary changes to bring any affected airplanes into compliance. On the basis of the FAA's response and pending additional action, on January 28, 2004, the Safety Board classified Safety Recommendation A-03-015 "Open—Acceptable Response" and Safety Recommendation A-03-016 "Open—Acceptable Alternate Response."

1.12 Wreckage Information

The airplane came to rest in the grass about 155 feet right of the runway 36R centerline and 5,979 feet from the approach end of the runway. The airplane was aligned on a magnetic heading of about 070° and in a slight (about 20°) right-wing-down attitude. The right main landing gear assembly collapsed, and the airplane was supported by its nose landing gear, left main landing gear, and the lower surface of the right wing. The fuselage remained largely intact, but the right wing and the fuselage immediately adjacent to it exhibited substantial impact and fire damage. The right side of the fuselage also exhibited impact damage (including punctures and metal buckling) and extensive fire and heat damage (including paint blistering and some areas of burn-through). The right wing, slats, flaps, and ailerons showed evidence of substantial impact, fire and heat damage, and the right engine was separated from the wing at its wing-to-pylon attachments. Soot deposits were observed on portions of the lower fuselage and most of the right side of the fuselage. (Figure 2 is a photograph of the damage to the right side of the airplane.) The left

side of the fuselage, left wing, and the nose and tail sections exhibited minimal impact or fire damage.

Figure 2. Photograph of the damage to the right side of the airplane.

The R1 and L1 passenger/emergency exit doors are located aft of the cockpit on the right and left side of the fuselage, respectively. During postaccident examination, the R1 door was closed, its door control handle was in the closed position, and its slide-arming lever was in the armed position. However, the L1 door was found in the full-open position, and the evacuation slide/raft was found deployed and inflated on the ground near the nose of the airplane. The slide/raft remained connected to the airplane by its mooring line.[33]

The L1 emergency door control handle was in the open position. The L1 slide's triangular red manual inflation handle (which is used to inflate the slide/raft if it fails to automatically inflate upon opening) and the rectangular white slide/raft disengage handle (which is located beneath the girt flap assembly and is used to release the slide/raft from the airplane in the event of a water landing) were found on the cabin floor near the R1 door. The manual inflation handle has a red reflective bracket and is stenciled with the word PULL in white lettering; the handle is normally attached by a cable to the inflation

[33] The slide/raft mooring line is intended to keep the slide/raft near the airplane after it is released from the girt following an emergency water landing.

cylinder. The slide/raft disengage handle is webbed and has the word PULL stenciled in red lettering; it is normally attached by Velcro at the base of the upper girt assembly under the girt cover flap. The slide/raft disengage handle is normally used only during emergency evacuations after a water landing (ditching). (Figure 3 shows FedEx's MD-11/-10 emergency evacuation door trainer, with the girt flap assembly in place. Figure 4 shows FedEx's MD-11/-10 emergency evacuation door trainer, with the girt flap assembly lifted.)[34] The distance from the accident airplane's L1 doorsill to the ground was 16 feet 10 inches instead of the usual distance of 16 feet 3 inches because of the failed right main landing gear.

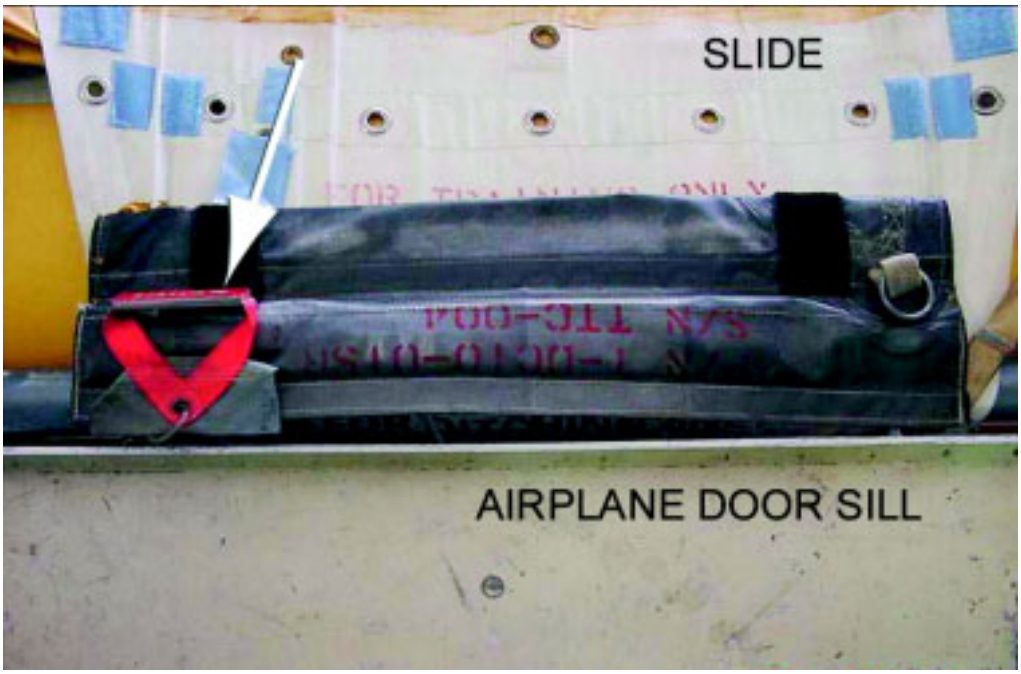

Figure 3. FedEx's MD-11/-10 emergency evacuation door trainer, with the girt flap assembly in place, as it would appear when the door/slide is opened. The arrow indicates the manual inflation handle.

[34] For additional information regarding the L1 emergency evacuation door and slide/raft, see section 1.12.4.

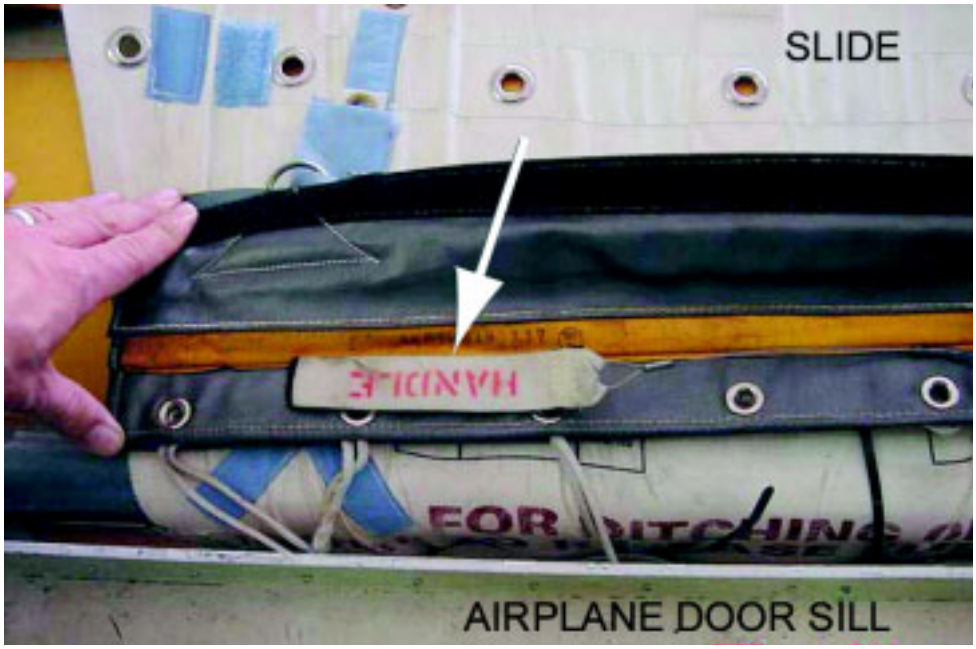

Figure 4. FedEx's MD-11/-10 emergency evacuation door trainer, with the girt flap assembly lifted. The arrow indicates the slide/raft disengage handle.

The cockpit, its furnishings, and the nonrevenue crewmember cabin area (the area located directly behind the cockpit door and in front of the cargo barrier, including the four courier seats) remained intact and exhibited no fire, smoke, or soot damage. All cockpit and passenger cabin area oxygen masks were stowed, and all cabinets and stowage compartments were intact, with their doors closed. The captain and first officer evacuation tapes[35] were deployed through their respective open cockpit windows. The lavatory and the cockpit doors were open, and the rigid cargo barrier door, which allows access to the main deck cargo compartment from the passenger cabin area, was found closed and secured by the first firefighters to board the airplane.

1.12.1 Tire and Other Markings on the Runway

Examination of tire markings on runway 36R revealed that the airplane touched down on the left main landing gear first about 564 feet from the approach end of the runway and 9 feet right of the runway centerline. The tire markings showed that the right main landing gear touched down about 613 feet from the approach end of the runway and 45 feet right of the runway centerline.

[35] The two cockpit evacuation tapes are thin (about 1 inch by 3/16 inch) ribbons of reinforced synthetic material that are located in compartments above the cockpit sliding windows. These tapes are intended to allow crewmembers to descend to the ground if the L1 and R1 emergency exit slides are not useable during an emergency evacuation.

The tire marks made by the forward tires on the left and right main landing gear assemblies were offset and misaligned from the tire marks made by the aft tires on those assemblies. On the basis of the relative positions of the tire marks on the runway, the Safety Board calculated that the airplane was yawed about 5.4° nose left of the runway heading when it touched down on the runway. (This yaw angle is consistent with the results of the Board's performance study, which is discussed in section 1.16.1.1.) The Board also calculated that the cockpit was about 20 feet right of the runway centerline when the airplane touched down.

The tracks from the forward and aft inboard tires on the right main landing gear assembly disappeared about 43 feet after they touched down. A large, sprayed fluid stain (about 8 feet in diameter) was located on the runway where the forward and aft inboard tire tracks disappeared. At the Safety Board's request, Boeing analyzed samples of the sprayed fluid; this analysis revealed that the substance was Military Specification 5606 hydraulic fluid, which is commonly used in landing gear shock struts. Also, the tracks from the forward and aft inboard tires reappeared about 10 feet farther down the runway. The markings on the runway indicated that the right main landing gear assembly moved to the left and then back to the right.

The first evidence of airframe contact with the runway was observed about 2,891 feet from the touchdown point. Scrapes from the right outboard flap/hinge were observed, along with evidence of the right main landing gear assembly collapse, about 12 feet farther down the runway. Evidence of fire and soot was observed on the runway and ground from about 2,999 feet north of the touchdown point to the airplane wreckage, and gouges in the runway from contact with the right engine began about 3,085 feet from the touchdown point.

1.12.2 Landing Gear Assemblies

The nose and left main landing gear assemblies were found down, locked, and undamaged, with their struts and tires pressurized. No problems were noted with the assemblies' wheels, tires, or brakes. The right main landing gear collapsed during the landing roll, and the outer cylinder fractured into six pieces. The upper end of the outer cylinder and a portion of the midsection remained attached to the airframe landing gear attachment fitting by the forward and aft trunnion bolts. The lower end of the right main landing gear cylinder remained attached to the piston assembly by the shock strut torque links.

Pieces of debris from the right main landing gear assembly were found along the runway from the initial touchdown point to the airplane wreckage location. The debris nearest the initial touchdown point (which was 564 feet from the approach end of the runway) was recovered about 378 feet from the touchdown point and was identified as the right main landing gear shock strut main chamber pressurization valve. Other debris from the right main landing gear was recovered along the next several hundred feet of the runway. Other right main landing gear assembly components, including the piston, lower end of the outer cylinder, truck beam, fore and aft axles, and associated wheels, tires

(except the no. 3 tire), and brake assemblies, were located about 3,686 feet from the touchdown point and in the grass about 115 feet right of the runway centerline. The no. 3 tire (the forward inboard tire on the right main landing gear) was located in the grass about 450 feet from the right main landing gear assembly.

1.12.3 Cargo and Shipping Containers

All cargo containers were found securely locked in place inside the accident airplane, and the containers' positions were consistent with those recorded on FedEx's weight and balance manifest for the accident flight. All shipping containers were found securely locked in place, and the cargo locks showed no apparent damage. The only evidence of damage to the shipping containers (or the cargo within, when inspected), was from firefighting operations (for example, snozzle[36] penetration of the fuselage) or postfire activities (for example, removal of the jammed forward cargo door).

1.12.4 Postaccident Examination of the Emergency Evacuation Slides

Examination of the L1 emergency evacuation slide/raft (Pacific Inflatables part number [P/N] 5WD230100-101) at the accident site revealed that the slide's rigidity beams were inflated, with no evidence of damage to the slide material. The survival kit and the inflation bottle were attached to the slide/raft, and the inflation bottle's gauge indicated that the bottle was fully discharged. The L1 slide girt assembly was intact but had separated from the girt bar flap assembly at the L1 doorsill. The R1 emergency evacuation slide/raft (also Pacific Inflatables P/N 5WD230100-101) was not deployed.

The L1 and R1 emergency evacuation slides were transported to the manufacturer's facility for further examination. Examination of the R1 evacuation slide/raft confirmed that it had not been activated. When the R1 slide/raft was unfolded on the manufacturer's shop floor and inflated, it operated normally.

Examination of the L1 emergency evacuation slide/raft at the manufacturer's facility confirmed that the L1 slide/raft girt assembly, the snaps that secure the girt assembly to the girt, the Velcro that secures the slide/raft disengage handle, and the girt loops were intact. The girt loops were relaced, the slide/raft disengage handle was secured to the Velcro patch, and the cover flap was reattached to the girt. There was normal slack in the girt bar flap when it was snapped to the girt, and there was no damage to the assembly.

Examination of the L1 inflation cylinder gauge confirmed that the cylinder was fully discharged. The manual inflation cylinder was removed from the L1 slide/raft and the inflation valve was removed from the cylinder to test the valve pull force required to activate the valve. Examination of the L1 slide's inflation cylinder valve showed that

[36] The snozzle is a piercing nozzle on the fire truck that is used to penetrate an airplane's fuselage and dispense AFFF to extinguish fire inside the cabin or cargo area.

7 pounds of pull force was required to activate the valve when the inflation cylinder was pressurized, which was within the specified inflation valve pull force of 5 to 20 pounds. The manual inflation cable measured 14 inches, in accordance with the cable length design specifications.

1.13 Medical and Pathological Information

In accordance with Federal requirements, urine samples were obtained from the captain and the first officer and were examined by an independent laboratory. The samples tested negative for drugs of abuse.[37] Breath alcohol tests of the captain and first officer taken about 4 hours after the accident were negative.

1.14 Fire

A fuel-fed fire occurred after impact. According to the MFD alert report, MFD personnel were advised of the accident about 1226 and arrived at the accident site about 1228. The report indicated that the "main body of fire" was under control within 10 to 15 minutes of MFD's arrival at the site and that the fire was completely extinguished by 1322.

1.15 Survival Aspects

The captain exited the cockpit through the right-side cockpit window exit, and the first officer and the five nonrevenue FedEx pilots who occupied the cockpit jumpseat and rear courier seats exited through the left-side cockpit window exit. Two occupants received medical treatment for their injuries: (1) the first officer sustained friction burns to both hands while sliding down the evacuation tape, and (2) the cockpit jumpseat occupant sustained minor injuries when he landed on his right shoulder after he let go of the evacuation tape. Two other occupants later reported that they received minor injuries to their hands while using the evacuation tapes. No other injuries were reported.

1.15.1 Nonrevenue FedEx Pilot's Activation of the L1 Door/Slide

As the postaccident fire developed on the right side of the airplane, one of the nonrevenue FedEx pilots opened the L1 emergency evacuation door and pulled the manual inflation handle on the evacuation slide/raft.[38] However, the slide/raft separated from the airplane, and the airplane occupants exited through the cockpit window exits.[39]

[37] The postaccident analyses tested for amphetamines, phencyclidine, and metabolites of marijuana, cocaine, and opiates.

[38] When the cabin door is opened in the emergency mode, the evacuation slide/raft unfolds out of the airplane and should inflate automatically; however, if the slide does not automatically inflate, a crewmember can cause it to inflate by pulling the manual inflation handle. Pulling the manual inflation handle while the slide/raft is inflating automatically does not interfere with the inflation process.

During postaccident interviews, the nonrevenue FedEx pilot who opened the L1 door stated that, when the airplane came to a stop, he and the other three FedEx pilots who occupied the courier seats aft of the cockpit unbuckled their seatbelts, stood up, and saw white smoke starting to turn gray outside the R1 exit door. He stated that the cockpit door opened, and he heard the captain ask the air traffic controller if there was a fire; the controller confirmed that he saw smoke and fire coming from the airplane. The nonrevenue FedEx pilot stated that, because he was closest to the L1 door and observed no smoke on that side, he opened that door with the captain's permission. He stated that, when he lifted the emergency exit handle, the L1 door pneumatically opened upward, and the slide/raft deployed. However, the nonrevenue FedEx pilot reported that, when he noted that the slide/raft was angled straight down and had not yet inflated, he pulled the manual inflation handle. He stated that the slide/raft inflated, separated from the doorsill, and disappeared under the airplane.

The nonrevenue FedEx pilot estimated that about 10 seconds elapsed from the time the L1 door opened until he pulled the slide's manual inflation handle.[40] As previously discussed, both the L1 door manual inflation and slide/raft disengage handles were found on the cabin floor near the R1 door. The nonrevenue FedEx pilot stated that he did not pull any other handle on the L1 emergency evacuation slide/raft. He stated that the slide deployment on the accident airplane was the first actual deployment he had experienced.

1.15.2 Emergency Evacuation Videotape

Safety Board investigators obtained a videotape made by a bystander that showed the burning airplane and the evacuation process. Review of this videotape showed that the captain evacuated the airplane first, using the right cockpit window evacuation tape, about 57 seconds after the recording began.[41] The second crewmember to evacuate the airplane (the cockpit jumpseat nonrevenue FedEx pilot) exited using the left cockpit window evacuation tape about 15 seconds later. During the next 65 seconds, the videotape showed eight objects being thrown from the airplane. The third crewmember to evacuate the airplane (one of the courier seat nonrevenue FedEx pilots) exited the airplane using the left cockpit window evacuation tape about 138 seconds after the recording began. The videotape showed that, during the next 27 seconds, another five objects were thrown from the airplane. The last four crewmembers evacuated the airplane using the left cockpit window evacuation tape between about 165 seconds and 209 seconds after the recording began; the entire evacuation took about 152 seconds.

During postaccident interviews, some of the nonrevenue FedEx pilots who had been seated on the courier seats in the cabin indicated that they threw bags out the L1 door

[39] For additional information on the use of the emergency slide, see section 1.17.2.5.

[40] According to the slide/raft manufacturer, in accordance with FAA requirements, automatic slide inflation should take no longer than 6 seconds.

[41] During a postaccident interview, the bystander's son stated that his father began filming about 2 minutes after the airplane came to a stop in the grass.

and the left cockpit window while they were waiting to exit the airplane through the left cockpit window. The airplane occupants indicated that many of the bags contained international passports (which the pilots needed for international FedEx flight segments), as well as clothing, uniforms, and holiday presents.[42] During postaccident documentation of the airplane, investigators found no occupants' bags remaining.

1.15.3 Emergency Response

MFD fire station no. 33 and MEM ATCT records showed that, about 1226:44, MEM ATCT personnel made the initial notification of the accident via the primary crash phone in the tower. This notification automatically activated crash alarms at the MFD fire station, MFD dispatch (located in downtown Memphis), the MEM airport communications operator (located in the lower level of the airport terminal), the Tennessee Air National Guard, and the RMFD.

According to the transcript of ATC communications on the local control frequency, about 1227:56, the accident captain advised the local controller that there were seven people aboard the airplane.[43] According to MEM ATCT personnel, this information was repeated aloud within the tower but was not relayed to ARFF responders. However, as previously discussed, the airplane occupants successfully evacuated through the cockpit windows without ARFF assistance.

Two MFD station no. 33 ARFF vehicles were the first ARFF vehicle responders to reach the airplane and immediately began to fight the fire on the right side of the airplane. After the first MFD firefighting units arrived at the accident site, a command site was established west of the accident airplane, and firefighting and first aid efforts were initiated. A few minutes later, when the two RMFD vehicles arrived,[44] the on-scene commander instructed one of them to take up a position on the left side of the airplane and to use its snozzle[45] to apply firefighting agents in the airplane's main cargo compartment. The MFD action report stated that the main body of the fire was under control within 10 to 15 minutes after MFD firefighting units arrived at the site and was completely extinguished by about 1322. According to the MFD station no. 33 action report, all of the airplane occupants who were in need of on-scene medical treatment had received it and, by 1402, had been transported to local medical facilities for further examination and treatment as necessary.

[42] For information regarding FedEx's emergency evacuation procedures, see section 1.17.2.4.

[43] During postaccident interviews, FedEx personnel indicated that they sometimes transport as many as 27 occupants on their wide body "cargo" airplanes.

[44] For additional information about this delay, see section 1.15.3.1.

[45] According to the snozzle manufacturer, this was the first time the snozzle was used in firefighting after an accident. Postaccident interviews indicated that it worked effectively.

1.15.3.1 RMFD Emergency Response

The ARFF vehicles that were dispatched to the accident site by RMFD arrived several minutes after the MFD fire station no. 33 ARFF vehicles. According to the transcript of ATC communications on the ground control frequency, about 1228:08, RMFD ARFF personnel requested permission to travel to the accident site, and the MEM ground controller advised them to hold short of runway 27 because of landing traffic. A review of recorded radar data showed that, at that time, the arriving airplane was about 2.5 miles east of the end of runway 27. The ATC transcript showed that the ground controller began to brief a relief ground controller about 1228:58, and the briefing continued until about 1231:06.[46] During this time (about 1229:28), the arriving airplane touched down. About 1230:04 (during the briefing), the relief ground controller asked the ground controller, "want that fire vehicle out there too?" and, about 1230:06, the ground controller cleared the RMFD vehicles to cross runway 27. About 1231:20, the relief ground controller cleared the RMFD vehicles to proceed to the accident site.

According to postaccident interviews with MEM ATCT personnel, RMFD ARFF vehicles normally operate on the FedEx ramp, which is not part of the airport's movement area; therefore, it is not typically under the ATCT's control. The ATCT controllers indicated that the RMFD vehicles were not considered primary emergency responders. The November 1, 2000, letter of agreement between MEM ATCT, the airport authority, and MFD fire station no. 33 addressing airport emergency procedures did not specify response procedures for the RMFD, but it noted that the airport crash phone rings at the FedEx (RMFD) fire station. The ATC controllers indicated that RMFD personnel were considered a secondary source for ARFF services, or unofficial "mutual aid," although no formal mutual aid agreement was in effect.

1.15.3.2 Postaccident Federal Aviation Administration Actions

On March 1, 2004, the FAA issued a notice to all airport operators, ARFF management, and FAA airport certification safety inspectors (CertAlert No. 04-01). This notice described the circumstances of this accident and stated the following:

> Arriving ARFF units were surprised to see 7 personnel egress the aircraft. A briefing with the cargo operator after the accident revealed that on its MD-10 aircraft, there could be as many as 27 personnel on board, at any time. Additionally, in some configurations, personnel are located in the rear of the fuselage section. This is usually used during livestock transportation with the handlers in the rear, but may occur for other reasons.
>
> If, after the accident, the crew was unable to advise ARFF of the total personnel on board, some passengers could be trapped based on an assumption of expected and limited crew.

[46] According to MEM ATCT personnel, the ground controller was being relieved so he could participate in postaccident activities as described in FAA Order 8020.11B, *Aircraft Accident and Incident Notification, Investigation, and Reporting*.

> The FAA suggests that airport operators and/or ARFF crews contact their cargo operators and explore avenues to determine the number of personnel that could possibly be expected on a particular aircraft. If possible, pre-plan with cargo operations for a way to obtain personnel manifests for incoming flights. At the minimum, expect that there could be a far greater number of personnel aboard than expected.

1.16 Tests and Research

1.16.1 Airplane Performance Studies

1.16.1.1 Safety Board's Airplane Performance Study

The Safety Board conducted an airplane performance study, which used the pitch, bank, heading, and acceleration data recorded by the FDR to determine the load factors at the right main landing gear during the landing. This airplane performance study also integrated the FDR acceleration data with ground evidence (tire tracks and markings on the runway surface) to create an integrated flightpath and ground path for the accident airplane. The Board's study showed that, during the 20 seconds before touchdown, the airplane's descent rate was 12.5 feet per second (fps) with +/- 2.5-fps oscillations. At 1225:52.1, the airplane's left main landing gear touched down at a rate of about 12.5 fps; about 0.25 second later, the right main landing gear touched down at a rate of about 14.5 fps. By contrast, the Board's study identified vertical speeds of less than 6 fps at touchdown during the airplane's two previous landings. Figure 5 shows the airplane's vertical speeds (as identified by the Safety Board's performance study) during the accident landing and the two previous landings, with altitude displayed above.

The MD-10-10F design criteria require that the airplane's landing gear and associated structure must be capable of absorbing energy equivalent to a 10 fps vertical speed (descent rate) when landing at the airplane's maximum design landing weight of 375,000 pounds (in accordance with the landing design limits imposed by 14 CFR 25.473[47] through 25.487).[48] In addition, in accordance with Section 25.723, the main landing gear is designed to be capable of absorbing reserve energy that is equivalent to a maximum airplane descent rate of 12 fps (720 feet per minute [fpm]) when landing at the maximum airplane design landing weight. According to the Board's study, the right main landing gear was subject to a peak longitudinal load factor of about -0.18 G, a peak lateral load factor of about 0.38 G, and a peak vertical load factor of about 2.27 Gs during the landing.[49]

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[47] Title 14 CFR 25.473, "Landing Load Conditions and Assumptions," states that the airplane is assumed to contact the ground with a limit descent velocity of 10 fps at the design landing weight (the maximum weight for landing conditions at maximum descent velocity).

[48] The accident airplane's estimated landing weight was 358,450 pounds. Landing energy calculations accounted for the differences between the design maximum and actual landing weights.

[49] Landing gear certification criteria address energy absorption/rate of descent; there are no published G limits for landing gear certification.

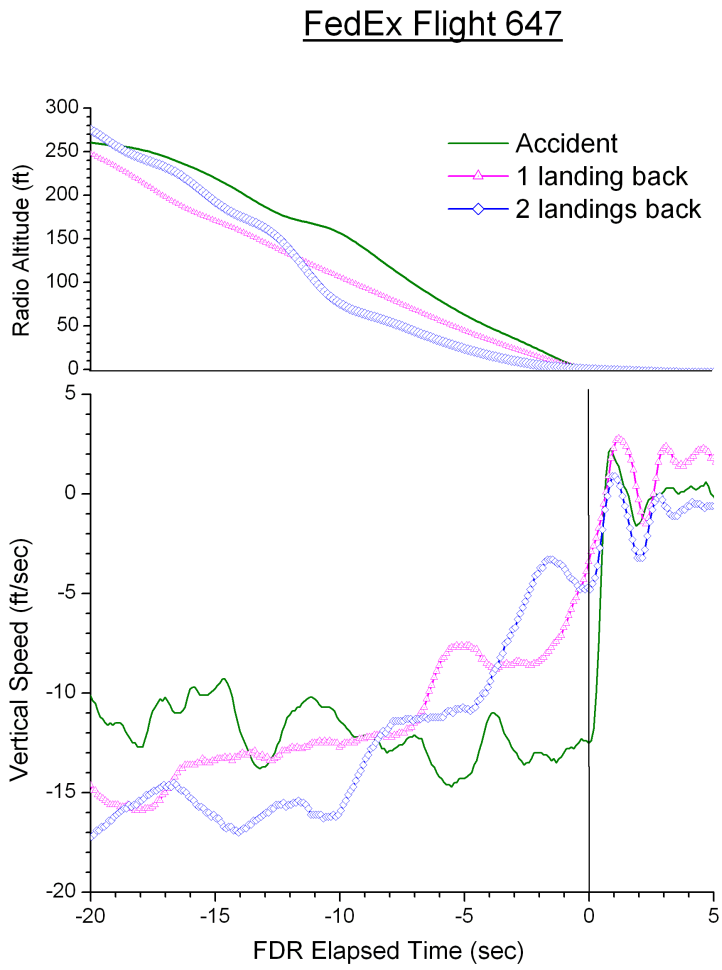

Figure 5. The airplane's vertical speeds (as identified by the Safety Board's performance study) during the accident landing and the two previous landings, with altitude displayed above.

The Safety Board's study of the FDR pitch data showed no evidence of an increase in the airplane's pitch attitude (flare) before touchdown. By contrast, during the two previous landings recorded by the FDR, the airplane's pitch increased during the seconds before touchdown, reaching nose-up pitch attitudes of more than 7°. Figure 6 shows the pitch attitudes recorded by the FDR during the accident landing and two previous landings.

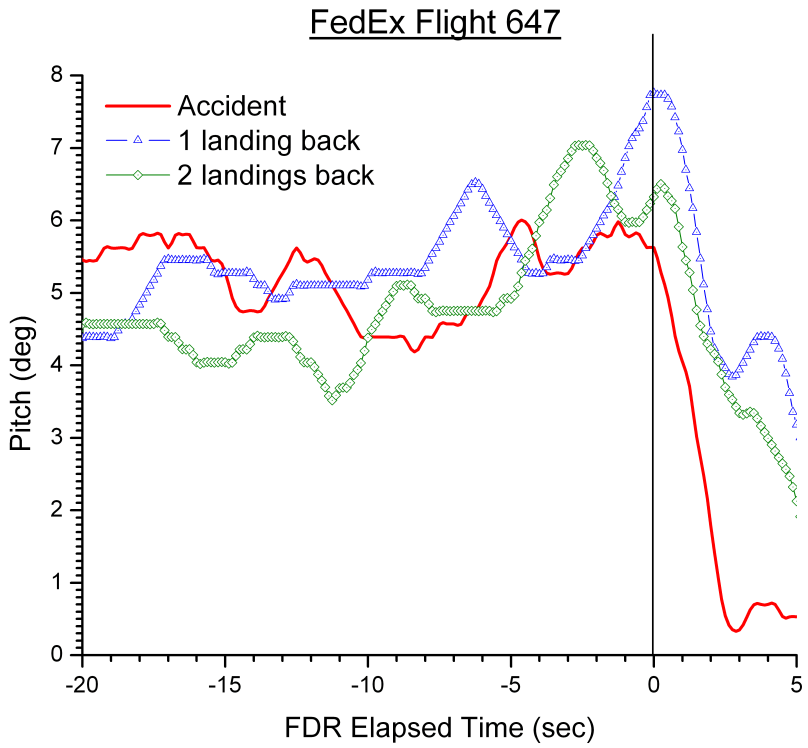

Figure 6. Pitch attitudes recorded by the FDR during the accident landing and two previous landings. The vertical black line (FDR elapsed time 0 seconds) represents the airplane's touchdown.

Although the FDR pitch data showed no evidence of a flare before the airplane touched down, the FDR elevator position data showed that the elevator moved from about 2.75° to 12.75° airplane nose up almost immediately after the left main landing gear touched down, just as the right main landing gear touched down. The study also revealed that the airplane's longitudinal axis was not aligned with its direction of flight or the runway when it touched down. Rather, the nose of the airplane was aligned on a heading of about 352.6°, about 5.4° left of the runway's magnetic heading of 358° and about 6.5° left of the airplane's ground track of about 359.1°. This information is consistent with the physical evidence noted in section 1.12.2.

1.16.1.2 Wind Derivation

The FDR recorded wind speed and direction every 4 seconds. The Safety Board derived wind speeds and directions for the 4 seconds between the recorded samples by comparing airplane positions (obtained from the airplane performance study acceleration integration) with FDR airspeed (converted to true airspeed) and heading data. The results

showed a left quartering headwind that ranged in speed between about 25 and 35 knots, with an average speed of about 30 knots and shifts in direction (from about 300º to 330°) between about 1225:10 and about 1225:42. Beginning about 1225:42, as the first officer began to align the airplane for landing, the derived wind speed decreased to about 20 knots. However, the wind derivation method assumed the airplane had zero sideslip, and, when the first officer maneuvered the flight controls to align with the runway, the airplane transitioned into a sideslip. This compromised the validity of the derived wind speeds during that portion of the approach; however, subsequent calculations that corrected for the sideslip indicated that the winds did not diminish significantly during the landing.

1.16.1.3 Boeing's Airplane Landing Energy Analysis

Boeing also conducted an airplane performance study (which produced results consistent with the Safety Board's performance study) and used those results to conduct a landing energy analysis.[50] The landing energy analysis showed that the total energy dissipated to the left main landing gear during the landing was 473,478 foot-pounds (ft-lb), and the energy dissipated to the right main landing gear during the landing was 563,478 ft-lb. According to 14 CFR 25.723(2)(b), "Shock Absorption Tests," the MD-10-10F main landing gear design requirement for reserve energy dissipation is 838,509 ft-lb total, or about 419,255 ft-lb each to the left and right main landing gear assemblies (assuming equal energy dissipation at each main landing gear assembly). Boeing's calculations showed that the total energy dissipated to the right main landing gear during the landing was about 34 percent greater than the design reserve energy requirement and about 19 percent greater than the energy dissipated to the left main landing gear.

1.16.2 Metallurgical Examination of the Right Main Landing Gear Assembly

The Safety Board visually examined portions of the accident airplane's right main landing gear assembly, including six sections of the fractured outer cylinder, at its materials laboratory. The visual examination of all of the fracture surfaces showed rough features with chevron markings consistent with tensile overstress. The chevron markings emanated from the shock strut chamber check valve hole located on the aft side of the cylinder just below the lower brace link.

Measurements of the check valve hole at the inboard origin area met Boeing's specifications, and the cylinder wall thickness at the failure plane met Boeing's thickness requirements, except for localized areas where it was greater than the requirements. Examination of the origin area revealed that the fracture initiated from both sides of the check valve hole inner diameter surface about 0.235 to 0.245 inch from the cylinder's

[50] The landing gear external ground loads associated with Boeing's reserve energy analysis included only vertical and drag loads applied to the landing gear; they did not include the additional effects of lateral or torsional loads that would be imposed on landing gear at touchdown in a sideslip.

inner surface. No evidence of preexisting fatigue was found. The check valve threads (only present near the outer diameter surface of the hole, which is not near the origin area) were relatively undamaged.

Examination of the unthreaded surface of the check valve hole from which the fracture initiated revealed significant circumferential tool marks and the presence of metallic deposits. Scanning electron microscope examination revealed that the fracture initiated at the base of the tool marks, which had a maximum depth of about 0.0015 inch. The area exhibited no evidence of fatigue or brittle zones.

Energy dispersive spectroscopy analysis of the cylinder base metal showed that the composition was consistent with the specified 300M steel. Hardness tests revealed that the fractured cylinder had a hardness consistent with applicable specifications.

1.16.3 Flight Simulator Study

The Safety Board used an MD-11 flight simulator that was backdriven[51] based on the accident airplane's FDR data to reconstruct the airplane's motions and the views from the cockpit during the approach and landing at MEM. All cockpit instrumentation and systems were operational, and the control wheel and rudder pedals moved as required to replicate the FDR. The simulator was programmed to provide a daytime visual scene of an airport with landing runway features similar to runway 36 at MEM and ground texture cues. The full-motion flight simulation was repeated several times to allow investigators to observe the internal and external cues available during the simulation. After the flight simulations, investigators (including representatives from FedEx and the Air Line Pilots Association [ALPA]) agreed on the following observations:

- It appeared that the control wheel approached full travel to the left and right several times during the approach.
- As the airplane descended through about 130 to 140 feet, it appeared to momentarily align with the runway centerline; however, control wheel and rudder inputs initiated during this alignment maneuver were not maintained, and the airplane's nose moved slightly left (back into the wind) as the airplane drifted to the right. This drift was evident from both pilot seats in the simulator and became markedly visible as the airplane descended through about 60 feet agl.

[51] To backdrive the flight simulator, investigators used data recorded by the FDR rather than a pilot input to drive the visual and motion systems of the simulator.

- When the airplane touched down, the control wheel and rudder pedals were close to their neutral positions, and it did not appear as if the pilots attempted to increase control column back pressure (to "flare" the airplane) before landing. (According to FedEx procedures, the pilots should have initiated the flare as the airplane descended through 30 feet agl.) The airplane was in a left "crab"[52] and right of the runway centerline when it touched down.

Investigators also determined that it would have been possible to conduct a successful go-around if initiated at various points during the approach and landing.[53]

1.17 Operational and Management Information

1.17.1 FedEx General Information

FedEx was incorporated in June 1971 and, in April 1973, began operating 14 corporate-type jet airplanes from the airline's hub at MEM. After the deregulation of the air cargo industry in 1977, FedEx began to expand, acquiring more and larger airplanes (including Boeing 727s and McDonnell Douglas DC-10s) and using multiple airports for its operations. In recent years, FedEx has added various models of Boeing, Airbus, Fokker, ATR, and Cessna airplanes to its fleet, including McDonnell Douglas MD-11s/-10s and Airbus A300s and A310s. At the time of the accident, FedEx operated a fleet of 624 airplanes with about 4,200 pilots.

1.17.2 FedEx Crew Training, Guidance, and Procedures

1.17.2.1 FedEx's Missed Approach/Go-Around Policy

According to chapter 6 of FedEx's flight operations manual (FOM), "the decision to execute a go-around is both prudent and encouraged anytime the outcome of an approach or landing becomes uncertain. FedEx considers the use of the go-around under such conditions as an indication of good judgment and cockpit discipline on the part of the flightcrew." Further, chapter 6 of the FOM states the following, in part:

> The decision a pilot must make before descending below the minimum altitude for the approach is not a commitment to land…
>
> The operational decision to continue an approach using visual means must be based on information the pilot accumulates throughout the approach. Since many variables are involved, the final decision to commit to a landing is the captain's and is primarily a judgment based on all relevant factors.

[52] The term "crab" refers to "the maneuvering of an aircraft partially into a crosswind to compensate for drift."

[53] For additional information, see the Operations Group Chairman Factual Report, Addendum 5 in the docket for this accident.

1.17.2.2 FedEx Crosswind Landing Guidance and Procedures

FedEx's MD-11/-10 flight manual (page 7-1-6-2) states the following regarding crosswind landings:

> Crosswind landings are accomplished by flying the final approach in a wings level attitude with a crab into the wind. At approximately 200' agl, align the fuselage with the runway by smoothly applying rudder and maintain runway centerline by lowering the upwind wing. In high crosswinds, consideration should be given to commencing the align maneuver prior to 200'. The align maneuver shall be established by 100' agl.

The flight manual also stated that, to ensure that the airplane is in the correct landing attitude and airspeed at touchdown, pilots should smoothly increase back pressure on the control column as the airplane descends through 30 feet agl, bringing the nose of the airplane up an additional 2° to 2.5° above its approach pitch attitude (resulting in about a 7° to 7.5° nose-up pitch attitude). The flight manual further stated that this pitch attitude should be established by 10 feet agl and that, subsequently, a constant pitch attitude should be maintained to touchdown.

The FOM listed the following guidelines for acceptable landing performance:

- Airspeed +/- 5 knots of the target speed on final
- Touchdown to occur in the touchdown zone
- Touchdown close to or on the centerline

On page 1-1-0-9, the FedEX MD-11/-10 FOM indicated that the maximum crosswind landing limitation is 31 knots. The manual also stated that pilots landing in crosswinds should adjust their approach airspeed by adding a wind additive of the greater of the following (not to exceed 20 knots):

- 5 knots
- 1/2 the steady wind in excess of 20 knots
- gust factor

1.17.2.2.1 Crewmember Descriptions of the Accident Approach and Landing

During postaccident interviews, the captain told investigators that he was satisfied with the first officer's flying techniques during the entire approach. He stated that the airplane was fully configured (landing gear extended, 35° of flaps) for the approach before the first officer disengaged the autopilot about 800 to 900 feet agl and that the autothrottles remained engaged throughout the approach. The captain stated that the first officer made the wind corrections necessary to keep the airplane tracking the extended runway centerline and maintained a proper glidepath during the approach. He indicated

that he did not observe anything "out of limits" during the approach and that he did not have to make corrective comments or control inputs.

The captain stated that, at 50 feet agl, the throttles automatically moved toward idle and that, about 30 feet agl, the first officer began to flare, increasing back pressure on the control column. He reported that the airplane landed on the runway centerline and in the touchdown zone, with the left and right main landing gear tires touching down at the same time and the nose gear lowering "normally."

The first officer stated that she maintained a wind correction angle of about 10° left of the runway heading and an approach airspeed of 149 knots until the airplane descended through about 200 feet agl. She reported that she then began to align the airplane's longitudinal axis with the runway centerline and initiated the flare about 30 feet agl. She stated that she did not perceive a need to adjust the throttles after the autothrottles moved them to idle. Both pilots indicated that the airplane touched down firmly and did not bounce.

According to FDR data, the airplane maintained about a 5° nose-up pitch attitude from about 1,500 feet agl until it touched down. No increase in pitch to dissipate airspeed and attain the proper landing attitude was observed in the FDR data as the airplane neared the runway.

1.17.2.3 FedEx Windshear Guidance

FedEx's MD-11/-10 flight manual defines windshear as "a rapid change in wind direction and/or velocity that results in airspeed changes greater than 15 knots or vertical speed changes greater than 500 fpm. Such conditions can be caused by convective conditions, frontal systems, and/or low altitude jet streams." According to the flight manual, pages 8-3A-4-1 and 8-3A-4-2, the MD-11 windshear alert and guidance system (WAGS)[54] is available from 1,500 to 50 feet radar altitude during the landing approach.

When the WAGS detects windshear, it generates an aural tail or head windshear announcement and illuminates a red or yellow WINDSHEAR annunciation in the upper left corner of the pilots' primary flight display, indicating decreasing or increasing airplane performance, respectively. If the windshear condition continues, the WAGS provides flight director or autopilot pitch guidance for an optimal flightpath through the windshear. When windshear conditions no longer exist, all windshear annunciations cease; however, the system continues to provide pitch and flightpath guidance until safe flight conditions are again achieved.

FedEx's MD-11/-10 flight manual recommended that pilots use standard operating techniques and procedures to prevent a "dangerous flight path situation from developing if inadvertent windshear is encountered." The manual recommended that pilots know the

[54] The WAGS is part of the autoflight system (AFS) and receives information from the central air data computer (ADC), inertial reference system (IRS), FMS, and other components of the AFS. When the central ADCs and IRSs provide data that indicate an adverse wind condition, the WAGS provides windshear alerts on the electronic instrument system and through the CAWS.

go-around decision criteria parameters and be prepared to execute an immediate go-around if those parameters are exceeded. Additionally, the manual stated that the nonflying pilot should closely monitor the vertical flightpath instruments, including vertical speed, altimeters, and glideslope displacement, and call out any deviations from normal. The flight manual also suggested that pilots take precautions "whenever probability of windshear exists but avoidance action is not considered necessary." For the approach and landing, these recommended precautions included achieving a stabilized approach no later than 1,000 feet agl, using 35° of flaps, and increasing approach airspeeds by up to 20 knots.

1.17.2.4 FedEx Emergency Evacuation Procedures and Guidance

According to the emergency evacuation guidance contained on page 2-13A-2-4 of FedEx's MD-11/-10 flight manual, after the airplane has stopped, the pilots should do the following:

- Verify that the outflow valve is open;
- Set the parking brake;
- Move the fuel levers to the off position;
- Command the evacuation;
- Move the engine fire handles to the down/discharge position;
- Pull/rotate the auxiliary power unit fire handle; and
- Unlock the cockpit door.[55]

Postaccident examination of the cockpit and review of the CVR indicated that the flight crew had successfully performed all items except those that were hindered by airplane damage.

On January 15, 2004, FedEx issued Flight Crew Information File (FCIF) 04-0020 (Vital), titled, "Emergency Evacuation Guidance," which stated, in part, the following:

> Emergency evacuations are potentially one of the more time-sensitive events in aviation. Each aircraft [flight manual] addresses the emergency evacuation procedures for that aircraft. This FCIF provides general policy concerning emergency evacuations.
>
> When the captain declares an emergency evacuation, the crew will follow the [flight manual] procedures and the captain will designate the evacuation route. In the event the captain is incapacitated, the crew chain of command will dictate who designates the route.

[55] The flight manual further specified that the pilots should unlock the cockpit door "to allow courier/cabin jumpseaters and/or emergency/security personnel access to the cockpit."

> During an emergency evacuation each crewmember and jumpseater will evacuate in the most expeditious manner possible. No one will take an unnecessary risk by taking time to salvage personal articles. Once out of the aircraft, the crew and jumpseaters should proceed to a safe place away from the aircraft. If possible, the first officer (2-man crew) or second officer (3-man crew) will carry a copy of the Notification of Dangerous Goods to give to the emergency responders.

On January 22, 2004, FedEx issued FCIF 04-0034 (Vital), which stated, in part, the following:

> This FCIF is to remind each crew member that they must be thoroughly familiar with their aircraft's…emergency evacuation procedures. This includes:
>
> 1. How to deploy the escape slide
> 2. If appropriate, how to detach the escape slide for use as a raft
> 3. How to escape through the cockpit windows
>
> The Jumpseat Certification guide has good information on evacuation, but if you have jumpseaters (even other crew members), you must brief them on how to perform an evacuation. If you are jumpseating, you should learn how to perform an evacuation from the aircraft.

1.17.2.5 FedEx Emergency Evacuation Training

The Safety Board's investigation revealed that FedEx's classroom training included a PowerPoint presentation that showed operation of the emergency exit door/slide in the emergency and manual modes. The classroom training also included a videotape showing the deployment of the emergency evacuation slide/raft and a close-up view of the girt flap assembly, including the manual inflation and slide/raft disengage handles. The classroom training emphasized that the slide/raft disengage handle is only to be used during an emergency water landing (ditching) operation. According to FedEx records, the captain, first officer, cockpit jumpseat occupant, and four courier seat occupants had completed FedEx MD-11/-10 emergency evacuation training during initial and subsequent recurrent training, as required.

FedEx's MD-11/-10 emergency exit door/slide trainer was used for emergency training and hands-on drills at its Memphis facility during initial and recurrent training for MD-10, MD-11, and DC-10 crewmembers.[56] The trainer's emergency slide/raft was permanently inflated and deployed and was attached to a pipe on the exterior of the trainer door (just below the doorsill). At the time of the accident, the door trainer did not include a girt bar flap assembly as would be found on an airplane. This assembly would have contained the manual inflation handle, the slide/raft disengage handle and the girt bar.[57] However, after the accident, FedEx installed a new girt bar flap assembly at the top of the slide/raft near the MEM trainer doorsill, with a manual inflation handle and a girt cover

[56] FedEx also used an emergency exit door/slide trainer at its facility in Anchorage, Alaska, for recurrent training for Anchorage-based MD-10, MD-11, and DC-10 crewmembers.

flap that could be lifted to reveal a slide/raft disengage handle.[58] According to FedEx personnel, the company also modified its procedures to require crewmembers to pull, or simulate pulling, the manual inflation handle during training sessions.

1.17.2.5.1 Regulatory Requirements and Federal Aviation Administration Oversight of Emergency Training

Emergency exit door/slide training devices are used extensively for flight and cabin crew emergency training in the aviation industry. The FAA principal operations inspector (POI) assigned to an operator is responsible for examination and approval of these devices. According to the guidance contained in FAA Order 8400.10, *Air Transport Aviation Inspector's Handbook*, POIs are to ensure that an operator's emergency exit door/slide training device(s) accurately represents the operation of the doors, slides, rafts, and other equipment that a crewmember might encounter on an airplane.

The handbook's specific guidance for flight crewmember emergency exit training[59] states that the emergency exit door training device should be designed so that students have the ability to do the following:

1. Experience the actual operation (open and close) of each exit in the normal and emergency modes;
2. Receive instruction on slide/raft deployment, transfer from one door to another, and detachment from the aircraft (or training device) of each type of slide/raft (if applicable); and
3. Actually use the slide/raft (this requirement needs to be accomplished only once, during initial new hire or equipment training).

More detailed guidance is contained in the cabin crewmember (flight attendant) emergency exit training section of FAA Order 8400.10,[60] which advises POIs to ensure that an operator's emergency exit door/slide training device(s):

1. Accurately represents the position and operation of the handles and hardware of the actual aircraft door;
2. Simulates both the normal and emergency modes;

[57] According to a FedEx training representative, the original girt bar flap assembly was removed from the door/slide trainer when FedEx installed a new slide/raft to the trainer. A FedEx training manager stated that the girt bar assembly was not reattached because of concerns that it might cause a tripping hazard for crewmembers during training. (FedEx's Anchorage trainer does not have a girt bar assembly but does have a red manual inflation handle at the base of the door.)

[58] This new installation did not have a girt bar; rather, a plastic pipe attached the inflated evacuation slide/raft to the trainer door sill.

[59] For additional information, see FAA Order 8400.10, *Air Transportation Inspector's Handbook*, volume 3, chapter 2, section 4.

[60] FedEx is a cargo operator and does not employ cabin crew/flight attendants; however, the guidance contained in this handbook pertains to flight or cabin crewmembers attempting an emergency evacuation. For additional information, see FAA Order 8400.10, *Air Transportation Inspector's Handbook*, volume 3, chapter 14, section 6.

3. Incorporates the actions required to operate the exit in the same manner as the actual door in both the normal and emergency modes of operation;
4. Requires representative forces to open the door in the emergency mode; and
5. Is equipped with a manual inflation handle, if applicable. The training program should address the fact that the inflation handle may not always be in the same location on similar aircraft.

The POI handbook further dictates that during each emergency drill, flight attendants should satisfactorily demonstrate the following:

1. During an emergency exit drill students must operate each type of emergency exit in the normal and emergency modes, including the actions and forces required for deployment of the emergency evacuation slides.
2. Ability to open exit properly by assuming correct body/protective position; to use door controls correctly; to ensure door is in open and locked position; to use manual slide inflation system to accomplish or ensure slide/raft inflation.

According to 14 CFR 121.417(c)(2)(i)(A), air carrier crewmembers (pilots and flight attendants) are required to **perform a drill** (emphasis added) and operate the equipment for "each type of emergency exit in the normal and emergency modes, including the actions and forces required in the deployment of the emergency evacuation slides." Also, Section 121.417(c)(2)(ii)(c) requires all crewmembers to **observe** (emphasis added) the "deployment, inflation, and detachment from the airplane (or training device) of each type of slide/raft pack."

As a result of issues identified during the Safety Board's investigation of the accident involving AirTran flight 356,[61] the Board asked the FAA to provide a "legal interpretation" of Section 121.417. The FAA provided a copy of a November 21, 2003, internal memorandum to "clarify crewmember training requirements on the B717 tailcone door and emergency evacuation slides." The memorandum stated that each flight attendant and pilot "must operate each type of emergency equipment in the normal and emergency modes including the actions and forces necessary in the deployment of the evacuation slides" during recurrent training. In addition, on December 2, 2004, the Board requested a legal interpretation of Section 121.417 specifically pertaining to hands-on training (to include pulling the manual inflation handle, as would be required in an emergency situation if the slide/raft did not inflate automatically when the door is opened) for all flight and cabin crewmembers.

The FAA responded in an internal memorandum dated December 23, 2004, which stated that the legal interpretation includes "hands-on" use of the manual inflation handle during the proficiency drill. (The Safety Board notes that, in July 1992, the FAA issued a bulletin advising its POIs that they were responsible for approving the training device and ensuring that the device is equipped with a manual inflation handle.)

[61] For additional information on this accident, see the Safety Board's public docket for accident NYC03FA067.

During postaccident interviews, the POI assigned to FedEx's certificate stated that the FAA approved FedEx's MD-11/-10 emergency door/slide training device and materials when the company first implemented them. He stated that typically FedEx management would notify the FAA of any changes or "enhancements" to approved training devices, and the FAA program managers for that fleet would then inspect and approve those changes. Additionally, the FedEx POI stated that the MD-11/-10 program managers had the opportunity to conduct surveillance of the door training devices during their observation of crewmember emergency exit proficiency checks; he estimated that they observe 15 to 20 proficiency checks each year. He stated that his interpretation of Section 121.417 was that FedEx crewmembers do not need to perform "hands-on" training of the slide/raft's manual inflation handle.

1.17.2.5.2 Previous Safety Board Emergency Exit Training Device Recommendation

During the investigation of the February 19, 1996, accident involving Continental Airlines flight 1943,[62] Safety Board investigators found that the aft flight attendant was unable to properly access the tailcone exit. Further investigation revealed that, because of differences between the tailcone emergency exit on the airplane and the tailcone emergency exit trainer, Continental flight attendants were unable to gain hands-on experience with the potential difficulties created by the interference of the aft jumpseat restraint system. As a result, on November 15, 1995, the Board issued Safety Recommendation A-97-10 asking the FAA to do the following:

> Amend Flight Standards Handbook Bulletin 96-02, "Guidelines for Crewmember Training on Aircraft Tailcones and Approval of Tailcone Training Devices," to include a requirement that if any portion of a restraint system is attached to the tailcone access plug door in the aircraft [that] might interfere with the opening of the door, the plug door training device must be equipped with the entire restraint system.

In a May 9, 1997, letter, the FAA stated that it responded to Safety Recommendation A-97-10 by issuing Flight Standards Handbook Bulletin 97-07, "Amendment to Guidelines for Crewmember Training on Aircraft Tailcones and Approval of Tailcone Training Devices." The amended bulletin emphasized that if any portion of a restraint system is attached to the tailcone access plug door in the aircraft that might interfere with the opening of the door, the plug door training device must be equipped with the entire restraint system. In a March 10, 1998, letter, the Safety Board classified Safety Recommendation A-97-10 "Closed—Acceptable Action."

[62] For more information, see National Transportation Safety Board, *Wheels-Up Landing, Continental Airlines Flight 1943, Douglas DC-9, N10556, Houston, Texas, February 19, 1996.* Aircraft Accident Report NTSB/AAR-97/01. (Washington, DC: NTSB, 1997).

1.17.3 FedEx Enhanced Oversight Program

As a result of a series of accidents and incidents (including the July 26, 2002, FedEx flight 1478 accident in Tallahassee, Florida),[63] the company's flight operations directorate implemented a project intended to identify technical and operational modifications that would improve air safety. On the basis of the project's findings, the company developed an enhanced oversight program (EOP) to identify and track pilots with deficiencies noted during training or required checkrides. (The Safety Board notes that, at the time of this writing, this program is unique in the aviation industry.) The EOP was finalized in late 2003 and was formally implemented in January 2004.

In a May 19, 2004, e-mail memorandum, FedEx's system chief pilot advised company personnel that the EOP was intended as "a self-defense program to better direct assets already being used. This is a tool to improve our safety and performance." The memorandum indicated that pilots who were assigned to the EOP would be scheduled for two line checks annually, which would be scheduled between their 6-month recurrent simulator training sessions,[64] thus providing management and training personnel with an opportunity to evaluate those pilots' proficiency every 90 days.[65] FedEx's system chief pilot estimated that about 215 pilots (out of about 4,200 total FedEx pilots) were in the EOP in late 2004. Of the 215 pilots, about 87 were MD-11/-10 pilots. (The EOP was not in effect until after the flight 647 accident happened, and both pilots have been in a non-flying status with FedEx since the accident. Therefore, neither pilot has been eligible to be listed in the EOP.)

According to an October 1, 2004, FedEx memorandum, the company had developed an EOP board of directors, which consisted of a system chief pilot as the chairman and the directors of flight operations, flight safety, flight standards, and flight training, to implement and oversee the EOP. The memorandum indicated that the board of directors meets monthly to review recent events, discuss pilot cases, and update the list of pilots in the EOP. The memorandum stated that the board of directors would maintain a database with which they would track EOP information and that the EOP would include any pilot who has one of the following documented training deficiencies:

- An UNSAT [unsatisfactory] training/evaluation within the preceding 12 months.
- Requiring [50 percent more training than the norm] in any phase of initial, transition, or upgrade training (ITU) in the preceding 12 months.

[63] For more information, see National Transportation Safety Board, *Collision With Trees on Final Approach, Federal Express Flight 1478, Boeing 727-232, N497FE, Tallahassee, Florida, July 26, 2002,* Aircraft Accident Report NTSB/AAR-04/02. (Washington, DC: NTSB, 2004).

[64] All flight crewmembers normally receive flight simulator training every 6 months. In addition, captains would normally receive an annual line check; first officers do not normally receive an annual line check.

[65] In addition, the company's Flight Standards Division personnel routinely conduct random line checks of FedEx flight crewmembers.

- Requiring extra training in more than one phase of ITU training in the preceding 12 months.

1.17.4 Federal Aviation Administration and Department of Defense Oversight of FedEx

The FAA flight standards district office in Memphis was responsible for oversight of the FedEx air carrier certificate. Four full-time inspectors were assigned to provide operational oversight of the airline: a POI, an assistant POI, an aircrew program manager, and an assistant aircrew program manager. Records indicated that the inspectors were tasked with 276 surveillance activities at FedEx from October 1, 2003, to September 30, 2004, including cockpit en route inspections, manual procedures, flight crew training records, dispatch procedures, check airmen observations, line check observations, simulator procedures, and training program effectiveness. At the time of the accident, 64 of the 276 surveillance activities had been completed.

The FAA also conducted three special inspections at FedEx since 1995. In August 1995, the FAA conducted a National Aviation Safety Inspection Program inspection. In April 1998, the FAA conducted an Office Safety Inspection Program inspection. In January 2000, the FAA conducted a Regional Aviation Safety Inspection Program inspection. All operational deficiencies found during these special inspections were corrected and closed as satisfactory by the FAA.

In addition, personnel from the Department of Defense Air Carrier and Analysis Office conducted a biennial survey at FedEx from January 28 to February 1, 2002. All inspected operational areas were found to meet or exceed standards. No operational deficiencies were noted in the Department of Defense report.

1.18 Additional Information

1.18.1 MD-11/-10 Flight Characteristics and Differences

As previously mentioned, the MD-10 is basically a DC-10 that has been modified with an advanced-technology flight deck and allows for MD-11/-10 commonality, so a pilot with an MD-11 type rating is qualified to fly the MD-10 if that pilot has completed the required differences training. Before it approved the common training and checking programs proposed by FedEx and Boeing, the FAA conducted extensive tests to evaluate system differences between the MD-11 and MD-10 and to validate the proposed training and checking programs.[66]

[66] The tests were conducted as outlined in FAA Advisory Circular (AC) 120-53. The only training program evaluated involved initial and transition training and type rating in the MD-11 with differences training for the MD-10. The FAA's Flight Standardization Board (FSB) report indicated that evaluations of MD-10 initial or transition training "may be evaluated at a later date."

According to the FAA's resultant Flight Standardization Board (FSB) report, dated May 9, 2000, the FAA conducted a two-stage series of tests. First, the FAA conducted a handling qualities comparison test to evaluate the effect of the MD-11 flight control computer (FCC)-908 software load in eliminating handling differences with the MD-10 during takeoff and landing.[67] Upon successful completion of the handling qualities comparison test, the FAA conducted tests to evaluate system differences and to validate the training programs proposed by FedEx and Boeing.[68]

According to the FSB report, the FAA's evaluation indicated that the MD-10 and MD-11 airplanes' handling qualities and systems were similar enough to warrant the same type rating. The FSB report further stated "takeoffs and landings performed in one variant are equivalent to those performed in other variants" and that as long as the MD-11 FCC-908 or later software was installed, a pilot could receive credit for 90-day takeoff and landing currency in either airplane (or a combination of both airplanes). With regard to mixed-fleet flight crews, the FSB stated "If crews fly MD-10 and MD-11 variants in a mixed-fleet, it is desirable but not mandatory for proficiency checks to alternate each six months for [captains], and annually for first officers."

During postaccident interviews, FedEx pilots and check airmen indicated that the differences in flight characteristics and handling were minimal. One check airman said he treated the airplanes as the same and taught the same techniques in each type. He stated that both airplanes were very automated but that you still had to "fly the airplane." Another check airman stated that he observed some differences between the MD-11 and MD-10 during landing (for example, he reported that he guards the autothrottles and does not let the throttles retard on the MD-10 during the flare and touchdown) but added that "you could land the MD-10 like an MD-11 and it would still be a safe landing."

1.18.2 Previous Safety Board Actions

During the late 1980s and early 1990s, the Safety Board issued three safety recommendations[69] to the FAA, suggesting it require commercial operators to review available pilot flight, training, performance, and disciplinary records. Additionally, during

[67] According to AC 120-53, the handling qualities comparison test consisted of "selected Part 61 or Part 121 pilot certification flight check maneuvers administered in the comparison…aircraft…while using a crew trained and experienced only in the base aircraft. Acceptable crew performance in completion of designated maneuvers, without differences training, establishes that the variant and base aircraft are sufficiently alike in handling characteristics to permit assignment."

[68] According to AC 120-53, these tests also "fully assess particular difference areas, examine implications of mixed fleet flying, assess special circumstances such as MEL [minimum equipment list] effects, and evaluate the effects of crew errors potentially related to the differences." These tests are conducted in a "realistic line flight environment that includes typical weather, routes, airports, ATC, and other factors [that] are characteristic of those that the aircraft will be operated in."

[69] Safety Recommendation A-88-141 was issued on November 3, 1988, and was classified "Closed—Unacceptable Action/Superceded on November 21, 1990. Safety Recommendation A-90-141 was issued on November 21, 1990, (superceding A-88-141) and was classified "Closed—Unacceptable Action" on October 20, 1992. Safety Recommendation A-93-014 was issued on February 19, 1993, and was classified "Closed—Unacceptable Action" on February 22, 1994.

the investigation of the December 13, 1994, accident involving American Eagle flight 3379,[70] Safety Board investigators again found deficiencies in an operator's procedures for evaluating applicant pilots' experience, skills, and abilities. As a result, on November 15, 1995, the Board issued Safety Recommendations A-95-116 through -119, which asked the FAA to do the following:

> Require all airlines operating under 14 CFR Parts 121 and 135 and independent facilities that train pilots for the airlines to maintain pertinent standardized information on the quality of pilot performance in activities that assess skills, abilities, knowledge, and judgment during training, check flights, initial operating experience, and line checks and to use this information in quality assurance of individual performance and of the training programs. (A-95-116)
>
> Require all airlines operating under 14 CFR Parts 121 and 135 and independent facilities that train pilots for the airlines to provide such information to the FAA for incorporation into a storage and retrieval system. (A-95-117)
>
> Maintain a storage and retrieval system that contains pertinent standardized information on the quality of 14 CFR Part 121 and 135 airline pilot performance during training. (A-95-118)
>
> Require all airlines operating under 14 CFR Parts 121 and 135 to obtain information from the FAA's storage and retrieval system that contains pertinent standardized pilot training and performance information for the purpose of evaluating applicants for pilot positions during the pilot selection and hiring process. The system should have appropriate privacy protections, should require the permission of the applicant before release of the information, and should provide for sufficient access to the records by an applicant to ensure accuracy of the records. (A-95-119)

In a February 11, 1997, letter, the FAA stated that it responded to Safety Recommendations A-95-117 through -119 by working with Congress on legislation that would require that pertinent pilot training records be provided to potential employers by previous employers. The FAA's efforts resulted in the Pilot Records Improvement Act (PRIA) of 1996,[71] which required that any company hiring a pilot for air transportation request and receive records from any aviation carrier, company, organization, or person that had employed a pilot applicant during the previous 5 years.

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[70] For more information, see National Transportation Safety Board, *Uncontrolled Collision with Terrain, Flagship Airlines, Inc., dba American Eagle Flight 3379, BAe Jetstream 3201, N918AE, Morrisville, North Carolina, December 13, 1994,* Aircraft Accident Report NTSB/AAR-95/07 (Washington, DC: NTSB, 1995).

[71] The authority and reference for the PRIA are found in Public Law 104-264, section 502, which is codified in 49 *United States Code* section 44703 (h), (i), and (j), and in FAA AC 120-68C. The PRIA became effective on February 7, 1997. The PRIA states, in part, "an air carrier that receives the records of an individual…may use such records only to assess the qualifications of the individual in deciding whether or not to hire the individual as a pilot. The air carrier shall take such actions as may be necessary to protect the privacy of the pilot and the confidentiality of the records, including ensuring that information contained in the records is not divulged to any individual that is not directly involved in the hiring decision."

Specifically, the PRIA required all 14 CFR Part 121, 125, and 135 air carriers to obtain training proficiency checks, airplane and route qualifications, and release from employment records from previous employers of pilot applicants before allowing an applicant to begin service as a pilot. The PRIA also required all air carriers to obtain from the FAA a pilot applicant's current medical certification and airman certification and any record of closed enforcement actions. The PRIA did not state that air carriers were required to obtain FAA airman records documenting failed flight checks for certificates and ratings. The FAA stated that the PRIA eliminated the need for a storage and retrieval system for pilot training records. In a June 2, 1997, letter, the Safety Board classified Safety Recommendations A-95-117 through -119 "Closed—Acceptable Alternate Action."[72]

As a result of its investigation of the July 13, 2003, accident involving an Air Sunshine Cessna 402,[73] the Safety Board issued two safety recommendations (A-05-01 and -02) regarding the importance of obtaining and using all pertinent pilot performance information in hiring decisions. Although there are no similarities between the Air Sunshine and FedEx Memphis accidents, the concept of the importance of having available and using all pertinent information to evaluate a pilot's capabilities applies to both. Safety Recommendations A-05-01 and -02 asked the FAA to do the following:

> Require all Part 121 and 135 air carriers to obtain any notices of disapproval for flight checks for certificates and ratings for all pilot applicants and evaluate this information before making a hiring decision. (A-05-01)

> Conduct a study to determine whether the number of flight checks a pilot can fail should be limited and whether the existing system of providing additional training after a notice of disapproval is adequate for pilots who have failed multiple flight checks. On the basis of the findings of the study, establish a flight check failure limit and modify the recheck training requirements, if necessary. (A-05-02)

[72] In an April 17, 1998, letter, the FAA stated that the PRIA, along with the requirements of 14 CFR 121.683 and 135.63, addressed most of the concerns in Safety Recommendation A-95-116. The FAA added that the air carrier training requirements contained in 14 CFR Parts 121 and 135 and the advanced qualification program were predicated on training to proficiency and, therefore, should certify pilot proficiency. Further, the FAA stated that much of the information included in the recommendation was already available to prospective employers. The FAA concluded by stating, "the inclusion of subjective evaluations in the permanent record by individual instructors, check airmen or FAA inspectors may have the net effect of making the training event a punitive experience rather than one where individuals can learn from mistakes." In a January 3, 2000, letter, the Safety Board classified Safety Recommendation A-95-116 "Closed—Reconsidered."

[73] For more information on this accident, see National Transportation Safety Board, *In-flight Engine Failure and Subsequent Ditching, Air Sunshine, Inc., Flight 527, Cessna 402C, N314AB, About 7.35 Nautical Miles West-Northwest of Treasure Cay Airport, Treasure Cay, Great Abaco Island, Bahamas, July 13, 2003,* Aircraft Accident Report NTSB/AAR-04/03 (Washington, DC: NTSB, 2004).

2. Analysis

2.1 General

The captain and first officer were properly certificated and qualified in accordance with, and had received the training and rest time prescribed by, Federal regulations and company requirements. The flight crewmembers possessed valid and current medical certificates appropriate for Part 121 flight operations.

Based on the available evidence, fatigue was not a factor in this accident. Although the CVR recorded the first officer coughing and clearing her throat numerous times, she stated that she was not sick, and there is no evidence that this (the coughing/clearing her throat) adversely affected the flight or her performance.

The accident airplane was properly certificated and maintained and was equipped and dispatched in accordance with applicable regulations and industry practices. There was no evidence of any preexisting powerplant, system, or structural failure.

Cargo loading for the accident flight was routine; no cargo loading anomalies were observed, and the airplane was operating within the prescribed weight and c.g. limits. No hazardous materials were on board the airplane. The accident airplane's cargo and its loading were not factors in the accident.

FedEx records indicated that the flight crewmembers had received the requisite initial, transition, and MD-11/-10 differences training. The Safety Board's review of the FAA's FSB report describing its evaluation of MD-11 and MD-10 handling characteristics and numerous postaccident MD-11/-10 flight crew interviews revealed only very subtle differences in flight handling characteristics during the landing phase between the two airplanes. The Safety Board notes that changes in handling characteristics resulting from differences in weight and balance can be much more significant than any differences that could be attributed to MD-11/-10 aerodynamic factors. Further, the significant flight control inputs that are needed when landing either an MD-11 or MD-10 in strong, gusty crosswind conditions (such as those encountered during the accident flight) would render any subtle differences in handling characteristics between the airplanes negligible. In any event, the FDR data show that the first officer momentarily applied flight control inputs to align the airplane with the runway as the airplane descended between about 200 and 160 feet agl; however, she did not maintain those inputs as the airplane neared the runway. In the absence of the necessary and significant flight control inputs during the crosswind landing, any possible differences in handling characteristics between the MD-11 and MD-10 would not be a factor for the pilot. Therefore, the Safety Board concludes that differences between the MD-11 and MD-10 handling characteristics during the landing phase were not an issue in this accident.

ATC was not a factor in the accident; however, in other circumstances, the ground controller's delay clearing RMFD ARFF vehicles to the accident site might have had more serious consequences. For additional information, see section 2.6.

The pilots were provided with weather forecasts, including AIRMET information, that indicated turbulence below 8,000 feet and strong northerly/northwesterly winds aloft and at the surface. Postaccident pilot and passenger statements and MEM airport surface weather information about the time of the accident indicated that the winds were strong and gusty out of the northwest; however, crew comments recorded by the CVR suggested that the pilots were not overly concerned about the weather conditions. Several airplanes landed without incident in similar conditions during the minutes before and after the accident. The winds identified in the Safety Board's performance study indicated that the existing weather conditions might have been responsible for the small airspeed gains and losses and the CAWS tail windshear alert experienced by the accident flight; however, there was no evidence of horizontal windshear significant enough to adversely affect the operation of the airplane. Additionally, a meteorological study conducted by MIT at the Board's request was consistent with the results of the Board's study. Therefore, the atmospheric conditions encountered during the approach and landing were within the performance capabilities of the airplane; there was no evidence of significant windshear.

The remainder of this analysis discusses the accident sequence, including flight crew performance, as well as emergency evacuation and MEM ATCT and ARFF issues.

2.2 The Accident Sequence

Postaccident interviews with the pilots and examination of the CVR and FDR data indicated that the en route portion of the accident flight from OAK to MEM was routine and that the pilots engaged in normal duties and discussions as the airplane neared MEM. Although they encountered turbulence and gusty crosswind conditions during the descent, both pilots reported that the approach to runway 36R was routine. A CAWS tail windshear alert sounded as the airplane descended through about 1,460 feet agl during the approach. The pilots indicated that because the alert was brief (1 to 2 seconds) and because the airplane remained in a stabilized approach, they determined that a go-around was not necessary and continued the approach. This decision was appropriate and consistent with FedEx's windshear policies.

FedEx's MD-11/-10 crosswind landing procedures dictate that, as the airplane descends through about 200 feet, the pilot should begin to apply control wheel and rudder inputs to align the longitudinal axis of the airplane with the runway centerline. This alignment procedure places the airplane in a sideslip, allowing the airplane to maintain the desired ground track and longitudinal alignment despite the crosswind conditions, as long as aileron and rudder control inputs are appropriate for those conditions. Then, as the airplane descends through about 30 feet, the procedures indicate that the pilot should smoothly increase back pressure on the control column to increase the airplane's pitch attitude (flare) to about 7° as appropriate for landing. Throughout final approach and

landing, the airspeed should remain within +/-5 knots of the target airspeed. Following these procedures would result in an airplane that is aligned with and centered on the runway centerline in about an appropriate landing pitch attitude and a proper descent rate and airspeed when it touched down.

During postaccident interviews, the captain and first officer described the landing and indicated that it was performed in accordance with FedEx's crosswind landing procedures. Both pilots stated that the landing flare was normal, including proper alignment with the runway centerline and compensation for wind conditions below 200 feet. The captain indicated that he thought they experienced a "strong gust" of wind during the landing, and both pilots described the landing as firm but otherwise normal. However, FDR evidence and physical evidence, including tire markings on the runway, indicated that the airplane touched down with both main landing gear assemblies and the nose gear well right of the runway centerline on a heading about 5.6° left of the runway heading. The evidence indicated that the airplane's left main landing gear touched down first about 500 feet from the approach end of the runway, and about 9 feet right of the runway centerline. The evidence further indicated that, almost immediately thereafter, the right main landing gear touched down about 45 feet right of the runway centerline about 49 feet further down the runway.

A series of simulations performed using the accident FDR data to backdrive an MD-11/-10 flight simulator indicated that the airplane maintained a stable condition, tracking along the runway centerline with an appropriate wind correction angle as it descended through 200 feet. The FDR evidence further indicated that the first officer began to apply left aileron and right rudder to align the airplane with the runway centerline about 160 feet (this became visually apparent in the simulator about 140 feet). However, the data and the simulations showed that these normal crosswind landing control inputs were only momentary; as the airplane descended below 100 feet, the aileron and rudder control inputs were neutralized and remained neutral until the airplane touched down. The simulations showed that, as a result of the neutralized flight control inputs, the airplane began to drift to the right and continued to drift to the right, with a 5° to 6° left crab angle, until it touched down. The winds at the time of the accident would have required a pilot's constant attention, significant flight control inputs along both the roll (control wheel) and yaw axes (rudder pedal), and continuous modulation of those inputs. Although the pilots received a windshear alert earlier in the approach, there was no evidence of a significant decrease in wind speed or change in wind direction that might have prompted the first officer to neutralize her crosswind-correcting flight control inputs as the airplane neared the runway.

The FDR data and the Safety Board's performance study showed that after the airplane descended through about 1,500 feet, its pitch attitude, descent rate, and airspeed remained fairly constant until touchdown (about 5° nose up, 720 fpm [about 12.5 fps], and 149 knots, respectively). However, according to FedEx's crosswind landing procedures, a pilot should begin to increase back pressure on the control column as the airplane descends through about 30 feet to increase pitch attitude and arrest the airplane's descent rate, dissipate airspeed, and bring the airplane into the correct landing attitude.

Nevertheless, the accident airplane's FDR data showed that the first officer did not increase the airplane's pitch attitude to arrest the airplane's rate of descent.

Therefore, on the basis of physical and FDR evidence, the Safety Board concludes that the first officer did not properly apply control wheel and rudder inputs to align the airplane with the runway centerline or apply appropriate back pressure on the control column to arrest the airplane's rate of descent before touchdown; as a result, the airplane touched down extremely hard while still in a crab.

Although the first officer had sufficient visual cues and time to recognize and correct for the deteriorating approach to landing (either by reapplying wind correction inputs and increasing back pressure on the control column to arrest the airplane's rate of descent before touchdown or by performing a go-around), she did not do either.[74] (The Safety Board notes that FedEx policy states that "the decision to execute a go-around is both prudent and encouraged anytime the outcome of an approach or landing becomes uncertain;" it is unlikely that either pilot would have hesitated to perform a go-around in an effort to avoid a possible reprisal.) Because there are no reasonable explanations for the first officer's failure to take corrective action during the late stages of the approach, and because of her history of poor performance, the Safety Board examined methods that identify pilots who may require additional oversight or training to ensure consistent operational performance. For additional information, see section 2.4.

Although the first officer was the flying pilot and did not apply proper flight control inputs during the final moments of the approach, the captain, who was also a check airman, was responsible for monitoring her performance (especially because he was conducting a line check of the first officer during the accident flight) and ensuring the safety of the flight. According to the CVR transcript, as the airplane approached MEM, the captain provided the first officer with information and advice appropriate for the flight and consistent with his role as a line check airman. However, the CVR did not record any comments by either pilot after the airplane descended through 200 feet during the approach. During postaccident interviews, the captain told investigators that he did not perceive any reason to comment or advise the first officer during that stage of the approach and landing. However, the FDR data (as displayed to investigators through the flight simulator sessions) showed that the first officer neutralized her wind-compensating flight control inputs as the airplane descended through about 100 feet and that the airplane subsequently began to drift to the right of the runway centerline. Although it may have been difficult for the captain, as the nonflying pilot, to immediately recognize that the first officer had neutralized her flight control inputs, the Board's flight simulation sessions showed that as the airplane's drift to the right continued uncorrected, the drift became markedly notable from both pilots' seats as the airplane descended through about 60 feet.

The Safety Board understands that a line check airman must balance the need to keep the flight safe with the potential for students to learn from their mistakes; however, in

[74] The first officer did move the control column slightly aft immediately before the airplane touched down; however, the input was too late to affect the airplane's pitch attitude and descent rate before touchdown.

this case, the captain allowed the airplane to deviate from established and recognizable performance standards at the most critical stage of the approach, without comment or correction. The captain had sufficient time to observe and react to the airplane's drift and the first officer's failure to arrest the airplane's rate of descent as it neared the runway. The investigators (including representatives from FedEx and ALPA) who observed the simulations reported that there were clear indications that aspects of the approach needed correcting and that the captain should have taken corrective actions when these indications became apparent.[75] Therefore, the Safety Board concludes that the captain, who was conducting a line check of the first officer, did not adequately monitor the first officer's performance during the final stages of the approach and landing at MEM and failed to take or initiate corrective action to prevent the accident.

2.3 Failure of the Right Main Landing Gear Assembly

The Safety Board's metallurgical examination of portions of the right main landing gear assembly showed that the landing gear outer cylinder failed in overstress initiating at the shock strut chamber check valve hole surface. The fracture initiated at the base of several circumferential tool marks, which were up to 0.0015 inch deep. The Board's metallurgical examination indicated that these tool marks were not significant enough to have caused fatigue cracking at the tool mark location during the life of the landing gear. Aside from these tool marks, no significant deviations from drawing requirements were found.[76]

The MD-10-10F landing gear and associated structure were designed to absorb energy equivalent to a limit vertical speed (descent rate) of 10 fps (about 600 fpm) when landing at the airplane's maximum design landing weight (consistent with the landing design limits imposed by Sections 25.473 through 25.487). In addition, in accordance with Section 25.723, the MD-10-10F main landing gear is designed to be capable of absorbing reserve energy that is equivalent to a maximum airplane descent rate of 12 fps (about 720 fpm) when landing at the maximum airplane design landing weight. However, during the accident landing, the left main landing gear touched down at a rate of about 12.5 fps (about 750 fpm) and the right main landing gear touched down at a rate of about 14.4 fps (about 864 fpm). As previously mentioned, airplane performance studies conducted by Boeing indicated that the energy dissipated at the right main landing gear during landing was about 34 percent greater than the reserve energy that the landing gear was designed to withstand and about 19 percent greater than the energy dissipated at the left main landing gear.[77] In addition, the analyses revealed that peak lateral loads coincided with the excessive vertical loads. Therefore, the Safety Board concludes that the excessive vertical

[75] The captain should have verbally prompted flight control actions, commanded a go-around, or taken control of the airplane for a go-around or landing.

[76] Nickel deposits were found on the shock strut chamber pressurization/check valve hole surface, which is unusual but not considered contributory to the event.

[77] The landing gear external ground loads associated with Boeing's reserve energy analysis included only vertical and drag loads applied to the landing gear; they did not include the additional effects of lateral or torsional loads that might be imposed on landing gear at touchdown.

and lateral forces on the right main landing gear during the landing exceeded those that the gear was designed to withstand and resulted in the fracture of the outer cylinder and the collapse of the right main landing gear. The tool marks at the shock strut chamber check valve hole created a preferred site for initiation of the crack; however, the damage was too small to have caused the event if normal landing loads were involved.

2.4 Flight Crew Performance—Oversight

The Safety Board's review of FedEx's pilot training procedures and oversight at the time of the accident revealed that, consistent with other operators in the aviation industry, it focused on a pilot's performance on the day of the checkride with little or no review of that pilot's performance on checkrides months or years earlier.[78] The Board is concerned that this single-event focus does not allow a carrier to monitor changes or patterns in a pilot's performance history that could provide significant information about the competency of a pilot. For example, in this case, the first officer's repeated substandard performances on checkrides were addressed as singular events that did not require further evaluation or monitoring after the checkride was satisfactorily completed. Yet, postaccident review of the first officer's training history and postaccident interviews suggested a pattern of below-standard performance.

In January 2004, as a result of a series of operational accidents and incidents involving FedEx flights, FedEx implemented an enhanced oversight program (EOP) to identify and track pilots who have demonstrated performance deficiencies or failures in the training environment. The EOP provides identified pilots with additional oversight (two additional line checks annually for first officers and one additional line check annually for captains),[79] thus providing FedEx management and training personnel with an opportunity to evaluate those pilots' proficiency and performance every 90 days. Additionally, the EOP board, which is made up of company training and flight standards directors, meets monthly to review recent events and discuss identified pilots' case histories. This increased level of monitoring a pilot's performance helps the company determine if deficient performance demonstrated during a checkride is indicative of the pilot's overall performance. If FedEx's EOP had been in effect when the first officer failed her checkrides in 1999 and/or 2001, she would certainly have received additional company scrutiny and training.

According to FedEx representatives, the EOP was intended "as a tool to improve our safety and performance" and to allow FedEx training personnel to better focus its training efforts. The company believed that review of a pilot's performance history during checkrides may provide valuable information about the skills and capabilities of that pilot. A pattern of failures and/or inconsistent performance would indicate performance deficiencies that could adversely affect the safety of flight. The EOP allows FedEx

[78] Typically, when a pilot fails a checkride, only the failed items are reviewed during the recheck.

[79] As previously indicated, FedEx flight crewmembers normally receive simulator training every 6 months. In addition, captains would normally receive an annual line check; FedEx first officers normally do not receive annual line checks.

training and management personnel to work with pilots to identify the reasons for the deficiencies and better focus the company's resources (oversight, training, etc.) to improve safety. The Safety Board notes that at the time of this writing, FedEx is the only Part 121 air carrier operator that has implemented this type of proactive program.

Over the years, the Safety Board has repeatedly noted the value of using information regarding a pilot's past performance to assess that pilot's current and future performance and overall abilities. For example, as a result of three accidents in the late 1980s/early 1990s, the Board issued three safety recommendations that asked the FAA to require air carriers to conduct substantive background checks of prospective pilots before they are hired. Subsequently, as a result of the December 13, 1994, accident involving American Eagle flight 3379, the Board issued four additional pilot-performance and training-documentation-related safety recommendations. In response to these recommendations, in 1996, the Pilot Records Improvement Act (PRIA) was enacted. In addition, as a result of the July 13, 2003, accident involving an Air Sunshine Cessna 402, the Board issued two more safety recommendations addressing pilot performance, checkride failures, and record-keeping.

These actions, including the PRIA, address a company's responsibility to review a pilot's history of performance when evaluating the candidate for hire. However, the PRIA does not allow use of these preemployment records after a pilot is hired. Additionally, despite the availability of their own postemployment pilot performance and training information, operators have not traditionally used this information to conduct ongoing pilot evaluations. Pilot oversight programs similar in concept to FedEx's EOP would allow operators to extend the important concept behind the PRIA (gathering all the available information to make informed decisions) to the ongoing evaluation and oversight of pilots in their employment.

On the basis of the value of using information regarding a pilot's past performance to assess that pilot's current and future performance and overall abilities, the Safety Board concludes that a proactive program, similar in concept to FedEx's EOP, in which flight crewmembers who have demonstrated performance deficiencies or experienced training failures are identified and given additional oversight and training would be beneficial to flight safety. Therefore, the Safety Board believes that the FAA should require all 14 CFR Part 121 air carrier operators to establish programs for flight crewmembers who have demonstrated performance deficiencies or experienced failures in the training environment that would require a review of their whole performance history at the company and administer additional oversight and training to ensure that performance deficiencies are addressed and corrected.

2.5 Survival Factors Issues

2.5.1 Emergency Exit Door/Slide Operation and Training

All seven FedEx pilots on board the accident airplane had received FedEx's MD-11/-10 emergency exit door/slide training, which consisted of initial and annual recurrent training.[80] FedEx conducted initial and subsequent biennial recurrent training sessions on its MD-11/-10 emergency exit door/slide trainers, with alternating biennial recurrent training presented in a classroom video presentation. The emergency slide/raft on the door trainer was permanently inflated and deployed, and FedEx crewmembers were required to use the slide during their initial training.

The Safety Board's review of FedEx's MD-11/-10 emergency exit door/slide trainer at its training facility in Memphis revealed significant differences between the trainer and the L1 emergency exit door/slide that the courier seat nonrevenue FedEx pilot operated during the accident evacuation.[81] Most significantly, there was no girt bar flap assembly (and, thus, no manual inflation or disengage handles) installed on FedEx's MD-11/-10 emergency exit door/slide trainer[82] at MEM. FedEx's door trainer configuration eliminated an opportunity for FedEx crewmembers to become familiar with the location and appearance of these handles, which would have helped them identify the handles under emergency conditions. Additionally, the door trainer did not reinforce the amount of time involved in inflating the slide/raft (6 seconds) because the slide/raft on the trainer door was already inflated and deployed when the training crewmember opened the trainer door.

Further, at the time of the accident, FedEx's emergency exit training program did not require crewmembers to simulate pulling a manual inflation handle during the training sessions.[83] All of the FedEx pilots on the accident airplane observed a video presentation showing the use of the manual inflation handle during training every year (which helps provide crewmembers with knowledge about door operation); however, this method of training does not adequately provide crewmembers with the skills required to operate the door/slide. For example, without hands-on training on a door trainer equipped with a manual inflation handle, it would be difficult for crewmembers to gain experience with the specific physical steps associated with opening the door and use of the manual inflation handle. Direct hands-on experience is beneficial in the development of the skills and habit

[80] Federal regulations regarding crewmember emergency training (Section 121.417) state that flight and cabin crewmembers must perform emergency exit drills "in the normal and emergency modes, including the actions and forces required in the deployment of the emergency evacuation slides" during initial training and during biennial recurrent training.

[81] The Safety Board notes that the R1 emergency exit door/slide was not usable because of the fire and smoke on the right side of the airplane.

[82] FedEx had MD-11/-10 emergency exit door/slide trainers at MEM and Anchorage, Alaska.

[83] As previously indicated, FedEx has since modified its procedures and requires crewmembers to pull, or simulate pulling, the manual inflation handle.

patterns a crewmember needs to open the door and use the handle during emergency conditions.

In addition, although the manual inflation and disengage handles are located near each other, they are separated by the girt bar flap, which must be lifted to access the disengage handle. Use of the disengage handle causes the slide/raft to separate from the airplane, which would not be desirable in this case (use of the disengage handle normally occurs only during emergency evacuations after water landings). Therefore, the Safety Board concludes that the nonrevenue FedEx pilot who opened the L1 emergency exit mistakenly pulled both the manual inflation and slide/raft disengage handles because he was not sufficiently familiar with their location and operation, thus separating the slide/raft from the L1 doorsill.

Although the FAA confirmed in a November 2003 memorandum that the flight and cabin crewmember emergency exit training requirements should be equivalent, the guidance contained in FAA Order 8400.10, *Air Transportation Aviation Inspector's Handbook*, includes a more detailed description of the emergency exit training requirements for cabin crew than for flight crew, including the requirement to pull the manual inflation handle. During postaccident interviews, the FAA POI assigned to FedEx stated that his interpretation of this regulation was that flight crews did not have to pull the manual inflation handle during training. However, in a December 2004 memo, the FAA confirmed that 14 CFR 121.417 requires both flight and cabin crews to pull the manual inflation handle during training.

The Safety Board concludes that the guidance contained in the flight crew emergency training section of FAA Order 8400.10, *Air Transportation Aviation Inspector's Handbook*, is not adequate for POIs to use in ensuring that emergency exit door/slide training for flight crewmembers is as comprehensive as that which cabin crewmembers receive and is as comprehensive as intended by the regulation. Therefore, the Safety Board believes that the FAA should amend the emergency exit training information contained in the flight crew and cabin crew sections in FAA Order 8400.10, *Air Transportation Aviation Inspector's Handbook*, to make the emergency exit door/slide training described in the flight crew section as comprehensive as the cabin crew emergency training section of the POI handbook.

The Safety Board further concludes that FedEx's inadequate hands-on emergency procedures training and the differences between the trainer and the door/slide installation on the accident airplane contributed to the unintentional release of the slide/raft. Further, the Safety Board is concerned that pilots flying for other Part 121 operators may not be receiving the proper emergency exit training (since it is possible that other POIs may also have erroneously interpreted the regulations). Therefore, the Safety Board believes that the FAA should verify that all 14 CFR Part 121 operators' emergency door/slide trainers are configured to accurately represent the actual airplane exit door/slide and that their flight crew emergency exit door/slide training provides the intended hands-on emergency procedures training as described in 14 CFR 121.417, to include pulling the manual inflation handle.

2.5.2 Cockpit Window Emergency Evacuation Issues

Because neither the L1 nor the R1 door could be used for the evacuation (the L1 slide/raft was inadvertently disconnected and there was fire on the right side of the airplane), the occupants evacuated through the captain and first officer sliding cockpit side windows and used the evacuation tapes. The two escape tapes—thin (about 1 inch by 3/16 inch) ribbons of reinforced synthetic material—are located in compartments above these cockpit windows and are intended to allow crewmembers to descend to the ground if the L1 and R1 emergency exit slides are not usable during an emergency evacuation.

Evaluation of a witness-provided videotape of the emergency evacuation showed that about 152 seconds passed between the time that the first and last occupant exited the burning airplane. During this time, the crewmembers did not evacuate the airplane in an uninterrupted flow. Although the captain and cockpit jumpseat nonrevenue pilot evacuated relatively quickly, the videotape showed delays between subsequent evacuating crewmembers. During these delays, the escape ropes were available but unused, and several pieces of baggage were thrown from the airplane. The elapsed time between successive crewmembers exiting the airplane was as much as 63 seconds. During postaccident interviews, several crewmembers reported that they were offloading bags while they waited in line to exit the airplane through the cockpit exits. During subsequent documentation of the cockpit, jumpseat, and cargo compartments, investigators found no crewmember baggage. It is evident that the delays were the result of the offloading of crewmembers' personal bags[84] and not because they were waiting for other crewmembers to exit or had difficulty using the cockpit egress system. The Safety Board concludes that most of the FedEx pilots on board the accident airplane showed poor judgment and exposed themselves to unnecessary risk when they delayed their evacuation from a burning airplane to salvage personal items.

After the accident, FedEx issued a bulletin to crewmembers that stated, "During an emergency evacuation each crewmember and jumpseater will evacuate in the most expeditious manner possible. No one will take an unnecessary risk by taking time to salvage personal articles." This bulletin articulated a policy similar to the policy that passenger-carrying air carriers have expressed to passengers for years.

2.6 Memphis ATCT Actions and Issues

Although the MEM ATCT controllers were not a factor in this accident or the effectiveness of the emergency response, the Safety Board notes that in different accident circumstances, some MEM ATCT controller actions might have had more serious consequences. For example, after the accident, the MEM ground controller held the RMFD ARFF vehicles, which were responding to the accident from FedEx's ramp on the north side of the airport, short of runway 27 because of landing traffic. This delay was

[84] During postaccident interviews, several occupants indicated that they salvaged the bags because they contained items they needed for their job (for example, passports, clothes, and uniforms). Additionally, some occupants reported that some bags contained holiday gifts.

exacerbated when the controller did not clear the RMFD vehicles to cross runway 27 immediately after the landing airplane was clear of the intersection.[85] The ground controller subsequently cleared two airplanes to cross after the landing airplane and before he cleared the RMFD vehicles to the accident site. The RMFD vehicles were delayed by almost 2 minutes after the initial request to cross the runway. It should be noted that the MEM ground controller did immediately clear all MFD vehicles to the accident site.

Although RMFD is staffed 24 hours a day/7 days a week and has routinely participated in MEM airport emergency drill exercises, there was no formal mutual aid agreement between MSCAA and RMFD addressing RMFD responsibilities and involvement in emergency situations. However, RMFD vehicles operated routinely on the airport, and the ground controller was not unaccustomed to handling those vehicles. Therefore, the Safety Board questions the MEM ground controller's decision to delay the RMFD ARFF vehicles' response to a burning airplane on the airport. The Safety Board considers it important that controllers give priority to all ARFF vehicles assisting in fire-related emergencies on the airport even if some ARFF vehicles are not officially incorporated into the airport's emergency plan. Any traffic conflict that the controller perceived between the landing airplane and the RMFD ARFF vehicles should have been resolved (possibly by delaying the airplane's landing) so that the RMFD ARFF could proceed to the accident scene without delay. Although RMFD ARFF vehicles were not a required component of MEM emergency responses, the availability of such support was a benefit that should have been utilized optimally.

Additionally, the Safety Board noted that, after the accident captain advised MEM ATCT controllers of the number of people on board the airplane, the local controller announced this information to others in the tower cab, but neither he nor the ground controller relayed this information to ARFF personnel. The evacuation was in progress when the ARFF responders arrived, and this information would have assisted them in accounting for all occupants, if needed. In this case, because none of the occupants were incapacitated, the only result was that the ARFF responders reported being surprised to see more people evacuating the airplane than they had expected. However, in other circumstances, this lack of pertinent information could have resulted in delayed rescue efforts. When ARFF responders arrive at an accident site involving a passenger-carrying flight, they would expect occupants in the cabin, whereas with a cargo flight they may not. In such a case, if the flight crew was incapacitated and unable to advise ARFF personnel of additional occupants on board the airplane, ARFF personnel might assume that only the primary crewmembers were aboard the cargo flight, thereby endangering anyone remaining on board and unable to self-evacuate.

The Safety Board concludes that the RMFD ARFF response vehicles were unnecessarily delayed in providing ARFF assistance because the MEM ATCT ground controller did not give them priority over other nonemergency airport traffic; under other circumstances, this could have adversely affected ARFF efforts. The Safety Board further concludes that ATCT controllers should recognize the importance of relaying all available

[85] The Safety Board notes that during this delay the ground controller was briefing a relief ground controller so the ground controller could participate in postaccident activities.

pertinent information, including airplane occupant information, to ARFF personnel to assist them in ARFF efforts and decision-making. Therefore, the Safety Board believes that the FAA should inform all ATCT controllers of the circumstances of this accident, including the need to ensure that ARFF vehicles are not delayed without good cause when en route to an emergency and the need to relay the number of airplane occupants to ARFF responders. Further, the Safety Board believes that the FAA should, in cooperation with the MSCAA and MFD, modify the November 1, 2001, letter of agreement, titled, "Airport Emergency Procedures," to fully describe the protocol to be used for emergency responses, including RMFD ARFF equipment and personnel.

2.7 FDR Aileron Update Rate Issues

During its investigation of this accident, the Safety Board observed that the FDR-recorded aileron position data was not being updated at the rate required by Federal regulations. The Board's flight data study showed that the data for all four ailerons (inboard and outboard on the right and left wings) were being sampled once per 250 ms, more frequently than required by Federal regulations, but were only being updated at a rate of about once per 700 ms instead of once per 500 ms. The Safety Board has previously issued two related safety recommendations, recommending the following to the FAA:

> Require that all Embraer 145, Embraer 135, Canadair CL-600 RJ, Canadair Challenger CL-600, and Fairchild Dornier 328-300 airplanes be modified with a digital flight data recorder system that meets the sampling rate, range, and accuracy requirements specified in 14 *Code of Federal Regulations* 121.344, Appendix M. (A-03-015)

> Survey all aircraft required by Federal regulation to have a flight data recorder to ensure that the data recorded meets the rate, range, and accuracy requirements specified in 14 *Code of Federal Regulations* 121.344, Appendix M. (A-03-016)

In an August 11, 2003, letter, the FAA indicated that it was working with the airplane manufacturers and airworthiness authorities involved to address the issues discussed in Safety Recommendation A-03-015 and that it would take appropriate action to correct any deficiencies. With regard to Safety Recommendation A-03-016, the FAA stated that it would ask all airplane manufacturers not addressed in Safety Recommendation A-03-015 to provide FDR design criteria information for obtaining data in accordance with Section 121.344, Appendix M requirements. Upon review of the design criteria, the FAA would identify necessary changes to bring any affected airplanes into compliance. On the basis of the FAA's subsequent response and pending additional action, on January 28, 2004, the Safety Board classified Safety Recommendation A-03-015 "Open—Acceptable Response" and Safety Recommendation A-03-016 "Open—Acceptable Alternate Response."

The FAA is continuing its efforts to assess the FDR design criteria of all airplanes that are required to comply with the parameter requirements specified in Section 121.344,

Appendix M. This investigation further demonstrates that FDR sampling problems exist in large, older airplanes (the MD-10 is a DC-10 that has been retrofitted with an advanced-technology flight deck) as well as newly designed, small regional jets.[86] The discovery of improper FDR sampling/update rates in the MD-10 confirms that this issue is likely as widespread as originally believed.

Because in some circumstances, inadequate and/or inaccurate recorded aileron position could adversely affect the Safety Board's ability to identify and address the related safety issues involved in an accident, possibly allowing an unsafe condition to go unrecognized, the Safety Board concludes that the required recorded FDR data on the MD-10 should meet the rate, range, and accuracy requirements specified in 14 CFR 121.344, Appendix M. Therefore, the Safety Board reiterates Safety Recommendation A-03-016.

[86] Safety Recommendations A-03-015 and -016 were issued as a result of improper FDR sampling/update rates observed in newly designed, small regional jets.

3. Conclusions

3.1 Findings

1. The captain and first officer were properly certificated and qualified in accordance with, and had received the training and rest time prescribed by, Federal regulations and company requirements. The flight crewmembers possessed valid and current medical certificates appropriate for 14 *Code of Federal Regulations* Part 121 flight operations.

2. Based on the available evidence, fatigue was not a factor in this accident. Although the cockpit voice recorder recorded the first officer coughing and clearing her throat numerous times, she stated that she was not sick, and there is no evidence that this (the coughing/clearing her throat) adversely affected the flight or her performance.

3. The accident airplane was properly certificated and maintained and was equipped and dispatched in accordance with applicable regulations and industry practices. There was no evidence of any preexisting powerplant, system, or structural failure.

4. The accident airplane's cargo and its loading were not factors in the accident.

5. Differences between the MD-11 and MD-10 handling characteristics during the landing phase were not an issue in this accident.

6. Air traffic control was not a factor in the accident.

7. The atmospheric conditions encountered during the approach and landing were within the performance capabilities of the airplane; there was no evidence of significant windshear.

8. The first officer did not properly apply control wheel and rudder inputs to align the airplane with the runway centerline or apply appropriate back pressure on the control column to arrest the airplane's rate of descent before touchdown; as a result, the airplane touched down extremely hard while still in a crab.

9. The captain, who was conducting a line check of the first officer, did not adequately monitor the first officer's performance during the final stages of the approach and landing at Memphis and failed to take or initiate corrective action to prevent the accident.

10. The excessive vertical and lateral forces on the right main landing gear during the landing exceeded those that the gear was designed to withstand and resulted in the fracture of the outer cylinder and the collapse of the right main landing gear.

11. A proactive program, similar in concept to FedEx's enhanced oversight program, in which flight crewmembers who have demonstrated performance deficiencies or experienced training failures are identified and given additional oversight and training would be beneficial to flight safety.

12. The nonrevenue FedEx pilot who opened the L1 emergency exit mistakenly pulled both the manual inflation and slide/raft disengage handles because he was not sufficiently familiar with their operation, thus separating the slide/raft from the L1 doorsill.

13. The guidance contained in the flight crew emergency training section of Federal Aviation Administration Order 8400.10, *Air Transportation Aviation Inspector's Handbook*, is not adequate for principal operations inspectors to use in ensuring that emergency exit door/slide training for flight crewmembers is as comprehensive as that which cabin crewmembers receive and is as comprehensive as intended by the regulation.

14. FedEx's inadequate hands-on emergency procedures training and the differences between the trainer and the door/slide installation on the accident airplane contributed to the unintentional release of the slide/raft.

15. Most of the FedEx pilots on board the accident airplane showed poor judgment and exposed themselves to unnecessary risk when they delayed their evacuation from a burning airplane to salvage personal items.

16. The Rural/Metro Fire Department aircraft rescue and firefighting (ARFF) response vehicles were unnecessarily delayed in providing ARFF assistance because the Memphis air traffic control tower ground controller did not give them priority over other nonemergency airport traffic; under other circumstances, this could have adversely affected ARFF efforts.

17. Air traffic control tower controllers should recognize the importance of relaying all available pertinent information, including airplane occupant information, to aircraft rescue and firefighting (ARFF) personnel to assist them in ARFF efforts and decision-making.

18. The required recorded flight data recorder data on the MD-10 should meet the rate, range, and accuracy requirements specified in 14 *Code of Federal Regulations* 121.344, Appendix M.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable causes of the accident were 1) the first officer's failure to properly apply crosswind landing techniques to align the airplane with the runway centerline and to properly arrest the airplane's descent rate (flare) before the airplane touched down; and 2) the captain's failure to adequately monitor the first officer's performance and command or initiate corrective action during the final approach and landing.

4. Recommendations

4.1 New Recommendations

As a result of the investigation of the FedEx flight 647 accident, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

Require all 14 *Code of Federal Regulations* Part 121 air carrier operators to establish programs for flight crewmembers who have demonstrated performance deficiencies or experienced failures in the training environment that would require a review of their whole performance history at the company and administer additional oversight and training to ensure that performance deficiencies are addressed and corrected. (A-05-014)

Amend the emergency exit training information contained in the flight crew and cabin crew sections in Federal Aviation Administration Order 8400.10, *Air Transportation Aviation Inspector's Handbook*, to make the emergency exit door/slide training described in the flight crew section as comprehensive as the cabin crew emergency training section of the principal operations inspector handbook. (A-05-015)

Verify that all 14 *Code of Federal Regulations* (CFR) Part 121 operators' emergency door/slide trainers are configured to accurately represent the actual airplane exit door/slide and that their flight crew emergency exit door/slide training provides the intended hands-on emergency procedures training as described in 14 CFR 121.417, to include pulling the manual inflation handle. (A-05-016)

Inform all air traffic control tower controllers of the circumstances of this accident, including the need to ensure that aircraft rescue and firefighting (ARFF) vehicles are not delayed without good cause when en route to an emergency and the need to relay the number of airplane occupants to ARFF responders. (A-05-017)

In cooperation with the Memphis/Shelby County Airport Authority and Memphis Fire Department, modify the November 1, 2001, letter of agreement, titled, "Airport Emergency Procedures," to fully describe the protocol to be used for emergency responses, including Rural/Metro Fire Department aircraft rescue and firefighting equipment and personnel. (A-05-018)

4.2 Previously Issued Recommendation Reiterated in This Report

The Safety Board reiterates the following recommendation to the Federal Aviation Administration:

> Survey all aircraft required by Federal regulation to have a flight data recorder to ensure that the data recorded meets the rate, range, and accuracy requirements specified in 14 *Code of Federal Regulations* 121.344, Appendix M. (A-03-016)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

RICHARD F. HEALING
Member

ELLEN ENGLEMAN CONNERS
Member

DEBORAH A. P. HERSMAN
Member

Adopted: May 17, 2005

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5. Appendixes

Appendix A
Investigation

The National Transportation Safety Board was initially notified of this accident on December 18, 2003. A go-team was assembled in Washington, DC, and traveled to the accident scene. No Board Member traveled to the accident site.

The following investigative groups were formed during the course of this investigation: Airworthiness (Structures, Systems, and Powerplants), Air Traffic Control, Meteorology, Operations/Human Performance, Airport/Survival Factors, Airplane Performance, Flight Data Recorder, and Cockpit Voice Recorder.

Parties to the investigation were the Federal Aviation Administration, the Boeing Commercial Airplane Group, FedEx Express, Air Line Pilots Association, and the Memphis/Shelby County Airport Authority.

Public Hearing

No public hearing was held for this accident.

Appendix B
Cockpit Voice Recorder Transcript

The following is a transcript of the Allied Signal model 6022 CVR installed on the accident airplane. Only radio transmissions to and from the accident airplane were transcribed. This CVR transcript reflects excerpts from the 2 hours and 58 seconds recorded before power was lost to the CVR. All times are central standard time based on a 24-hour clock.

LEGEND	
CAM	Cockpit area microphone voice or sound source
HOT	Crew station voice or sound source
CAWS	Central Aural Warning System electronic voice
RDO	Radio communications transmitted from N364FE, FedEx Flight 647
CTR1	Radio transmission from first Memphis Center controller
CTR2	Radio transmission from second Memphis Center controller
APR1	Radio transmission from first Memphis Approach controller
APR2	Radio transmission from second Memphis Approach controller
TWR	Radio transmission from Memphis Tower controller
-1	Voice identified as the Captain
-2	Voice identified as the First Officer
-3	Voice of an unidentified jumpseat passenger
-?	Voice unidentified
*	Unintelligible word
#	Expletive
@	Non-pertinent word
( )	Questionable insertion
[ ]	Editorial insertion
...	Pause or interruption

Note 1: Times are expressed in central standard time (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 or phrase, where noted, refers to a name or a word not directly related to the operation, control or condition of the aircraft.

INTRA-COCKPIT COMMUNICATION		1 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1025:43 **START OF RECORDING** 1056:27 **START OF TRANSCRIPT**				
1056:27 **CAM-3**	still not feeling * well what's ahh ***.			
1056:33 **CAM-1**	nah she (was coughing) like crazy the other day. I think she's got pneumonia.			
1056:41 **CAM-3**	s* stay home.			
1056:43 **CAM-1**	I know it.			
1056:44 **CAM-3**	she's gonna make us sick.			
1056:46 **CAM-1**	I think so too.			
1056:49 **CAM-1**	it's a three leg line check from ah to re-qual *.			
1057:00 **CAM-3**	* be good.			

INTRA-COCKPIT COMMUNICATION		2 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1057:09 CAM-1	I think she would have if it hadn't been so much scrutiny on this line check.			
1057:13 [BREAK IN VERBATIM TRANSCRIPT until 1156:39]				
1132:11 [Captain discusses with First Officer expectations, arrival procedures and descent planning into the Memphis area.]				
1135:58 [Captain and First Officer discuss runway options for the F-M-S setup for the approach into Memphis.]				
1145:40 [First Officer briefs Captain on arrival and approach procedures into Memphis for runways two seven, as primary, and three six left, as secondary. Captain and First Officer discuss runway three six right as backup. The Captain briefs pre-selection of the I-L-S frequency for the nav/rad page of the F-M-S.]				
1156:39 CAM-1	@ whatever happens today I need I need to see a stable approach at a thousand feet. if for some reason we're not stable go around. all right?			
1156:52 CAM-2	yep no problem there.			

INTRA-COCKPIT COMMUNICATION		3 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1156:53 CAM-1	all right.			
1156:53 CAM-?	[sound similar to coughing]			
1156:55 CAM-1	but we don't have a # of a lot of gas so # be stable.			
1156:59 CAM-2	got it.			
1157:19 CAM-2	here we go.			
1157:24 CAM-2	* expect ***considered a normal (operation) *** about a hundred ***.			
			1157:39 CTR1	FedEx six forty seven descend and maintain flight level two four zero.
			1157:44 RDO-1	roger descend to flight level two four zero FedEx six forty seven.
1157:49 CAM-1	two four zero.			

INTRA-COCKPIT COMMUNICATION		4 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1157:51 CAM-2	(okay).			
1158:55 CAM-1	let's see on the fix page I just set the airport. is that okay or do you want a particular runway?			
1159:01 CAM-2	um ***.			
1159:07 CAM-1	yeah we don't know what why it's **. * figure out what runway we're gonna ah land on I'll put that in there for you.			
1159:15 CAM-2	okay (good).			
			1159:27 CTR1	FedEx six forty seven contact Memphis one two seven point four.
			1159:31 RDO-1	one two seven point four FedEx six forty seven.
			1159:46 RDO-1	Memphis center FedEx six forty seven passing flight level two seven zero descending to two four zero.

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
		1159:52 **CTR2**	FedEx six forty seven Memphis center roger cross ten west of GILMORE at twelve thousand Memphis altimeter three zero one zero.
		1159:58 **RDO-1**	ten west of GILMORE at twelve thousand. three zero one zero FedEx six forty seven.
1200:04 **CAM-1**	twelve thousand.		
1200:11 **CAM-2**	[sound similar to throat clearing]		
1200:21 **CAM-1**	that point is five minutes ahead of us.		
1200:26 **CAM-?**	*.		
1200:34 **CAM-1**	I have three twenty now and the winds are… sixteen gusts to twenty two so…		
1200:42 **CAM-2**	*.		

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1200:43 CAM-1	…it's more favorable to the three sixes.			
1200:48 CAM-1	so we gotta go with the flow. I'll take care of the F-M-S. you call for (the runway).			
1201:18 CAM	[sound of two clicks]			
1201:20 CAM-2	[sound similar to throat clearing]			
1201:32 CAM	[sound of two clicks]			
1201:36 CAM-1	hey @ can I ask you to throw those meals back in the… box back there for us? sorry I missed doing that when I got up.			
1201:47 CAM	[sound of rustling]			
1201:49 CAM	[sound of click]			
1201:54 CAM	[sound of click]			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1201:59 CAM	[sound of rustling]		
1202:08 CAM-2	I just think we should start putting out slats about twenty miles on the other side of that and start *** pretty much the way…		
1202:16 CAM	[sound of click]		
1202:17 CAM-2	…it says because I'm… I'm ah st-still fairly unfamiliar with Memphis so…		
1202:23 CAM-1	yeah.		
1202:24 CAM-2	…I-I wanna get configured a bit earlier for that.		
1202:27 CAM	[sound of click]		
1202:27 CAM-1	do what you want… but here's a tip on Memphis. you know we're gonna be going down here…		

INTRA-COCKPIT COMMUNICATION		8 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1202:34 CAM-2	mmm-hmm.			
1202:34 CAM-1	…we're gonna be going downwind and make a left turn around to the three six runways and if they're stepping us down @ and trying to meter us in with guys coming in from Dallas and Atlanta and stuff they'll give you like a thousand feet at a time…			
1202:48 CAM-?	[sound similar to a cough]			
1202:48 CAM-1	…and you're coming passing BOWEN making the right turn there and they clear you to two thousand feet they're telling you your in. you're number one.			
1202:58 CAM-2	okay.			
1202:58 CAM-1	and you're probably gonna get an early turn in.			
1202:59 CAM-2	okay.			

INTRA-COCKPIT COMMUNICATION		9 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1203:00 CAM-1	so you wanna you wanna keep the thing coming down which means speed brakes and two fifty. don't let it slow back down on you.			
1203:06 CAM	[sound of two clicks]			
1203:07 CAM-2	okay.			
1203:08 CAM-1	to ahh hang glide in there you know.			
1203:12 CAM-2	okay in range checklist please.			
1203:14 CAM-1	roger.			
1203:15 CAM	[sound of two clicks]			
1203:16 CAM-1	that's just Memphis code you know… what's happening.			
1203:22 CAM-2	[sound similar to coughing]			

INTRA-COCKPIT COMMUNICATION		10 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1203:23 CAM-1	at least I see a lot of guys they'll ahh… they'll just let they stay in F-M-S speed the airplane will begin to start slowing down and go to two twenty and they're trying to get down and it doesn't go down…			
1203:35 CAM	[sound of click]			
1203:35 CAM-1	…worth a # at two twenty as you well know so.			
1203:37 CAM-2	yeah.			
1203:38 CAM-1	they get behind on the descent then they they're scrambling to get down and then ahh… they get down here and ah the F-M-S of course thinks you're going all the way out here to FREAZ and they turn you inside FREAZ and so now it's it just gets uglier from there on in.			
1203:55 CAM-2	*… yeah… [sound of chuckle] *.			
1204:07 CAM	[sound of click]			

INTRA-COCKPIT COMMUNICATION		11 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1204:08 CAM-1	otherwise the um trick to Memphis is like a lot of these busy airports it's just you're driving and you stay focused on that and make me do whatever you need done…			
1204:20 HOT-2	okay.			
1204:21 CAM-1	…just keep track (of) how far we are to land and what your configuration oughta be and you're it's ah work out fine.			
1204:29 HOT-2	sounds good.			
1204:31 CAM	[sound of click]			
1204:46 CAM-1	two ninety is the default…			
1204:48 HOT-2	yeah *.			
1204:49 CAM-1	…descent speed. which is just fine. that's what's in there.			

INTRA-COCKPIT COMMUNICATION		12 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1204:53 HOT-2	[sound similar to throat clearing] for some reason it's not going there though and I don't know why.			
1204:56 CAM-1	yeah it's at two ninety right now. that's what it'll be on in descents.			
1205:01 HOT-2	well yeah but it it didn't slow to but I wanted to get down anyway so that makes sense. ah what was the altimeter? three zero?			
1205:11 CAM-1	three zero one zero.			
1205:22 HOT-2	[sound similar to throat clearing] *.			
1205:27 CAM-1	altimeters.			
1205:30 HOT-2	three zero one zero.			
1205:32 CAM-1	three zero one zero.			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1205:34 **CAWS**	[sound of tone] altitude.		
		1205:37 **CTR2**	FedEx six forty seven contact Memphis approach nineteen one.
		1205:40 **RDO-1**	nineteen one FedEx six forty seven.
1206:00 **CAM-1**	@ the in range is complete.		
1206:01 **HOT-2**	thanks.		
		1206:07 **RDO-1**	Memphis center FedEx six forty seven is ah two hundred feet to go to be level at twelve thousand.
		1206:12 **APR1**	FedEx six forty seven heavy Memphis approach expect runway three six left. information Zulu. where you parking today?
		1206:19 **RDO-1**	we got Zulu. we're going in spot eight and we'll expect three six left FedEx six forty seven.

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
		1206:24 **APR1**	FedEx six forty seven heavy correct descend and maintain eight thousand.
		1206:28 **RDO-1**	roger out of twelve thousand descending to eight thousand FedEx six forty seven.
1206:32 **CAM-1**	three six left.		
1206:40 **HOT-2**	[sound similar to throat clearing]		
1206:40 **CAM-1**	we'll go ahh.		
1206:55 **CAM-1**	confirmed eight thousand…		
1206:55 **HOT-2**	eight thousand.		
1206:57 **CAM-1**	…and secondary's been activated.		
1207:03 **HOT-2**	thanks.		

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1207:05 **CAM-1**	(confirm that) ** it's set.			
1207:15 **CAM-1**	(east) KOLEY and five twenty one on the baro.			
1207:17 **HOT-2**	five twenty one set.			
1207:23 **CAM**	[sound of clicks]			
1207:31 **CAM-1**	all right you're set.			
1207:32 **CAM**	[sound of clunk]			
1207:34 **HOT-2**	if you would put ahh three six left in the fix page for me.			
1207:38 **CAM-1**	you bet.			
1207:49 **HOT-2**	thanks.			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1207:53 **HOT-2**	[sound similar to throat clearing]		
1207:54 **CAM**	[sound of click]		
1208:04 **CAM**	[sound of click]		
1208:13 **CAM**	[sound of whirring, similar to crew seat movement]		
1208:16 **CAM**	[sound of clicks]		
1208:57 **CAM-1**	oh god bluff city here we are again.		
1209:02 **HOT-2**	wow there's the pyramid.		
1209:03 **CAM-1**	yep.		
1209:04 **CAM**	[sound of double-click]		

INTRA-COCKPIT COMMUNICATION		17 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1209:07 **HOT-2**	[sound similar to throat clearing]			
1209:12 **CAM-1**	it's saying three twenty at sixteen gusts to twenty two. ten miles vis. it's still saying wind shear.			
1209:25 **HOT-2**	goodness.			
1209:28 **CAM-1**	(it's gonna be) at the airport.			
1209:30 **HOT-2**	[sound similar to coughing]			
1209:50 **CAM**	[sound of click]			
1210:15 **CAWS**	[sound of tone] altitude.			
1210:17 **HOT-2**	nine for eight.			
1210:23 **CAM-1**	nine thousand for eight thousand.			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1210:32 HOT-2	[sound similar to coughing]		
1210:41 HOT-2	*. [sound similar to coughing]		
1210:46 CAM-1	I don't see any other T-CAS targets but I'm sure there are a few. we may be the lead dog coming in here. there's another guy way over here.		
1210:56 HOT-2	[sound similar to throat clearing]		
		1211:24 APR1	FedEx six forty seven heavy reduce speed to two one zero then descend and maintain six thousand.
		1211:30 RDO-1	back to two ten then down to six thousand FedEx six forty seven heavy.
1211:35 HOT-2	[sound similar to throat clearing] reduce to two ten and back to (what/one) six thousand?		
1211:39 CAM-1	no descend to six thousand.		

INTRA-COCKPIT COMMUNICATION		19 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1211:41 HOT-2	yeah.			
1211:41 CAM-1	after we get to two ten knots.			
1211:42 HOT-2	two ten slats extend please.			
1211:47 CAM	[sound of click]			
1211:48 CAM	[sound of double-click]			
1212:11 HOT-2	[sound similar to throat clearing]			
1212:14 CAM-1	'kay there's BOWEN… one seventy five is the heading out of BOWEN.			
1212:21 HOT-2	oh thank you. [sound similar to throat clearing]			
1212:32 HOT-2	yeah forgot about that sorry.			

INTRA-COCKPIT COMMUNICATION		20 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1212:42 **CAM**	[sound of click]			
1212:50 **HOT-2**	[sound similar to throat clearing]			
1212:59 **CAM-1**	FREAZ is out there fourteen miles from touch down they seldom take you…			
1213:04 CAWS	[sound of tone] altitude.			
1213:04 **CAM-1**	…all the way out and turn you around…			
1213:05 **CAM**	[sound of clunk]			
1213:07 **CAM-1**	…and bring you in through FREAZ. we usually…			
1213:10 **HOT-2**	well before then.			
1213:11 **CAM-1**	…they'll do it before that so you gotta be **.			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1213:14 HOT-2	[sound similar to throat clearing]		
1213:16 CAM-1	airport's right here @.		
1213:17 HOT-2	yep.		
		1213:18 APR1	FedEx six forty seven heavy contact Memphis approach on one two four correction make it one two six point seven.
		1213:24 RDO-1	one two six point seven FedEx six forty seven.
1213:28 HOT-2	yep I see it.		
		1213:32 APR2	[transmission from controller to unidentified aircraft] all right thank you and he's a T-C-A violator we're gonna try to ah he's a class BRAVO violator we're gonna try to track him and see where he goes.
1213:35 CAM	[sound of click]		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) **SOURCE**	**CONTENT**	Time (CST) **SOURCE**	**CONTENT**
1213:38 **HOT-2**	ooh goodness.		
1213:53 **HOT-2**	[sound similar to throat clearing]		
		1213:54 **RDO-1**	FedEx six forty seven heavy is level at six thousand downwind.
1214:15 **HOT-2**	go with the flaps fifteen please.		
1214:16 **CAM**	[sound of three clicks]		
1214:17 **HOT-2**	[sound similar to throat clearing]		
		1214:33 **APR2**	FedEx six forty seven heavy Memphis approach maintain five thousand turn ten degrees right.
		1214:39 **RDO-1**	ten degrees right descend to five thousand FedEx six forty seven heavy.
1214:43 **CAWS**	[sound of tone] altitude.		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1214:48 CAM-1	six thousand for five thousand.		
1214:50 CAWS	[sound of tone] altitude.		
		1214:50 APR2	FedEx six forty seven heavy change your runway expect runway three six right.
		1214:55 RDO-1	roger three six right FedEx six forty seven heavy.
1214:56 HOT-2	[sound similar to coughing]		
1215:00 HOT-2	well you're the finger.		
1215:05 HOT-2	[sound similar to throat clearing]		
1215:06 CAM-1	done. three six right.		
1215:08 HOT-2	thank you.		

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1215:10 HOT-2	[sound similar to coughing]			
1215:21 CAM-1	HADYN at ah three thousand MAGEE at *.			
1215:33 CAM	[sound of click]			
1215:39 CAM-1	three six right's in the fix page and it's in the ah F-M-S you're loaded.			
1215:42 HOT-2	thanks.			
1215:44 CAM	[sound of whirring, similar to crew seat movement]			
1215:47 HOT-2	[sound similar to throat clearing]			
1216:04 HOT-2	[sound similar to throat clearing]			
			1216:11 APR2	FedEx six forty seven heavy reduce speed to one niner zero.

INTRA-COCKPIT COMMUNICATION		25 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
			1216:14 RDO-1	back to one ninety knots FedEx six forty seven heavy.
1216:18 CAM-1	*.			
1216:35 HOT-2	[sound similar to throat clearing]			
1216:36 HOT-2	[sound similar to coughing]			
1216:39 HOT-2	I don't know if you want anti ice or not?			
1216:41 HOT-2	**.			
1216:41 CAM-1	ahh yeah that'd be a good idea.			
1216:46 CAM	[sound of click]			
			1216:59 APR2	FedEx six forty seven heavy descend and maintain four thousand.

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) **SOURCE**	**CONTENT**	Time (CST) **SOURCE**	**CONTENT**
		1217:02 **RDO-1**	out of five thousand descending to four thousand FedEx six forty seven heavy.
1217:07 **CAM-1**	four thousand.		
1217:09 **CAWS**	[sound of tone] altitude.		
1217:15 **HOT-2**	[sound similar to throat clearing]		
1217:25 **HOT-2**	[sound similar to coughing]		
		1217:36 **APR2**	FedEx six forty seven heavy turn left heading zero niner zero.
		1217:40 **RDO-1**	left turn zero niner zero FedEx six forty seven heavy.
1217:46 **CAM**	[sound of click]		
1218:00 **HOT-2**	[sound similar to throat clearing]		

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1218:02 CAM-1	distance to the runway right here.			
1218:09 HOT-2	[sound similar to throat clearing]			
1218:10 HOT-2	we can go (and do) the approach check too.			
1218:11 CAM-1	approach check. briefing's complete to three six right. the altimeter is three zero one zero.			
1218:15 HOT-2	three zero one zero.			
			1218:15 APR2	FedEx six forty seven heavy turn left heading zero two zero join runway three six right localizer.
1218:20 HOT-2	arm please thanks.			
			1218:21 RDO-1	[sound similar to microphone key] zero two zero to join the localizer FedEx ah six forty seven heavy.
1218:23 HOT-2	[sound similar to throat clearing]			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1218:25 HOT-2	[sound similar to coughing]		
1218:35 CAM-1	okay um let's see three zero one zero.		
1218:38 HOT-2	three zero one zero.		
1218:40 CAM-1	and then loc is armed three are ahhh.		
1218:40 HOT-2	[sound similar to coughing]		
1218:43 HOT-2	five thirty five.		
1218:44 CAM-1	five thirty five minimums.		
1218:52 HOT-2	[sound similar to throat clearing]		
1218:53 CAM-1	nav aids're are checked.		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1218:55 HOT-2	thank you.		
1218:56 CAM-?	** checks.		
1218:58 CAM-1	approach checks complete.		
1218:59 HOT-2	thanks.		
1219:00 CAM-1	loc's alive.		
1219:02 HOT-2	[sound similar to throat clearing]		
1219:09 CAM-1	eighteen miles from touch down.		
		1219:10 APR2	FedEx six forty seven heavy reduce speed to one seven zero caution wake turbulence six and a half miles behind a heavy Airbus.
		1219:16 RDO-1	one seventy knots ah we're looking for the Airbus FedEx six forty seven heavy.

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1219:19 HOT-2	[sound similar to throat clearing]		
1219:20 HOT-2	*** (screw us up).		
1219:24 HOT-2	flaps twenty two please.		
1219:25 CAM-1	flaps twenty two.		
1219:25 CAM	[sound of two clicks]		
1219:28 CAM-1	I got an Airbus right here…		
1219:29 HOT-2	yep.		
1219:30 HOT-2	[sound similar to coughing]		
1219:30 CAM-1	…and another one out there looks like about level with us.		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) **SOURCE**	**CONTENT**	Time (CST) **SOURCE**	**CONTENT**
1219:31 **HOT-2**	[sound similar to coughing]		
1219:41 **HOT-2**	oops. [sound similar to throat clearing]		
		1219:46 **APR2**	FedEx six forty seven heavy descend and maintain two thousand.
		1219:50 **RDO-1**	out of four thousand for two thousand FedEx sixty forty seven heavy.
1219:53 **HOT-2**	[sound similar to throat clearing]		
1219:57 **HOT-2**	sorry about that.		
1219:58 **CAM-1**	*.		
1220:02 **HOT-2**	[sound similar to throat clearing]		
1220:13 **HOT-2**	[sound similar to coughing]		

INTRA-COCKPIT COMMUNICATION		32 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1220:20 **CAM-1**	I'm gonna turn the engine anti ice off.			
1220:25 **CAM**	[sound of click]			
1220:24 **CAM-1**	I don't think we need it.			
1220:28 **HOT-2**	[sound similar to throat clearing]			
1220:37 **HOT-2**	[sound similar to throat clearing]			
1220:38 **CAM-1**	the loc is captured. we're not yet cleared for the approach.			
1220:41 **HOT-2**	that's noted.			
1220:42 **HOT-2**	[sound similar to throat clearing]			
1220:44 **CAWS**	[sound of tone] altitude.			

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1220:46 CAM	[sound of click]			
1220:47 CAM-1	three thousand for two thousand.			
1220:49 HOT-2	three thousand for two thousand.			
1220:50 CAM	[sound of whirring, similar to seat movement]			
1220:52 HOT-2	[sound similar to throat clearing]			
			1220:56 APR2	FedEx six forty seven heavy advise when you have the airport.
1221:00 HOT-2	have the airport.			
			1221:00 RDO-1	FedEx six forty seven heavy has the airport.

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
		1221:03 **APR2**	FedEx six forty seven heavy cleared visual approach runway three six right maintain a hundred and seventy knots until MAGEE and you can contact tower now one one niner point seven so long.
		1221:13 **RDO-1**	one seventy to MAGEE and tower nineteen seven at MAGEE FedEx or now ahh * FedEx six forty seven heavy.
1221:22 **CAM-1**	hundred and seventy to MAGEE.		
1221:23 **HOT-2**	that's noted.		
1221:25 **HOT-2**	[sound similar to throat clearing]		
1221:26 **CAM-1**	(MAGEE/he) is ahh…		
1221:28 **CAM**	[sound of click]		
1221:30 **CAM-1**	…five and a half miles ahead.		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) **SOURCE**	**CONTENT**	Time (CST) **SOURCE**	**CONTENT**
1221:40 **HOT-2**	[sound similar to throat clearing]		
		1221:53 **TWR**	FedEx six forty seven heavy Memphis tower number two following a heavy Airbus two mile final caution wake turbulence runway three six right gain and loss of ten n-* short final runway three six right cleared to land.
1222:03 **CAM**	[sound of click]		
		1222:04 **RDO-1**	number two cleared to land on three six right FedEx six forty seven heavy spot eight today.
		1222:05 **TWR**	*.
1222:05 **HOT-2**	[sound similar to throat clearing]		
1222:24 **CAM-1**	how 'bout.		
1222:26 **HOT-2**	[sound similar to throat clearing]		
1222:29 **HOT-2**	sounds like a good idea.		

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1222:31 CAM-1	how 'bout four extra knots.			
1222:32 HOT-2	okay.			
1222:34 HOT-2	[sound similar to throat clearing]			
1222:47 CAM-1	I don't like to add extra speed but you know three or four knots can make a lot of difference…			
1222:53 HOT-2	[sound similar to a sigh]			
1222:53 CAM-1	…if you're bumpin' around back and forth ** foot.			
1222:55 HOT-2	**.			
1222:57 HOT-2	[sound similar to throat clearing]			
1222:58 HOT-2	good enough.			

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1223:03 HOT-2	let's go with ah landing gear down. before landing checklist please.		
1223:08 HOT-2	[sound similar to throat clearing]		
1223:10 HOT-2	glideslope's alive.		
1223:10 CAM-1	glideslope's alive.		
1223:18 CAM	[sound of clunk]		
1223:24 CAM-1	before landing checklist. spoilers are armed. the gear's down in and three green.		
1223:28 HOT-2	checked.		
1223:30 CAM-1	flaps are twenty two. flaps to go.		
1223:31 HOT-2	[sound similar to throat clearing]		

INTRA-COCKPIT COMMUNICATION		AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT	Time (CST) SOURCE	CONTENT
1223:36 **CAM-1**	there's MAGEE.		
1223:36 **HOT-2**	yep.		
1223:38 **HOT-2**	[sound similar to throat clearing] and flaps thirty five.		
1223:40 **CAM-1**	roger.		
1223:41 **CAM**	[sound of click]		
1223:48 **HOT-2**	[sound similar to throat clearing]		
1223:52 **CAWS**	[sound of warble] tailwind shear. tailwind shear. tailwind shear.		
1223:55 **CAM-1**	* okay it's all right let it let it work it.		
1223:57 **HOT-2**	goodness.		

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1223:58 CAM-1	stay back within F-M-S speed **.			
1224:14 HOT-2	[sound similar to throat clearing]			
1224:19 CAM	[sound of clunk]			
1224:23 CAM	[sound of click]			
1224:27 CAWS	one thousand.			
1224:29 CAM-1	visual. stable.			
1224:29 CAM	[sound of click]			
1224:30 CAM-1	we got a nine thousand foot runway @…			
1224:33 HOT-2	'kay.			

INTRA-COCKPIT COMMUNICATION		40 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1224:34 CAM-1	…and we land at a hundred and forty (six). a pretty good headwind oughta work out okay…			
1224:37 HOT-2	[sound similar to throat clearing]			
1224:41 CAM-1	…keep it out of the grass.			
1224:44 HOT-2	I'll do my very best [sound of chuckle, followed by sound similar to throat clearing]			
1224:52 HOT-2	autopilot's coming off.			
1224:53 CAM-1	all right.			
1224:55 CAM	[sound of thump]			
1224:56 CAWS	[sound of warble] autopilot.			
1225:02 CAM-1	checklist is complete. you're cleared to land.			

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1225:04 **HOT-2**	thanks.			
1225:08 **CAWS**	five hundred.			
1225:11 **HOT-2**	[sound similar to throat clearing]			
1225:29 **HOT-2**	[sound similar to throat clearing]			
1225:45 **CAM**	[sound of click]			
1225:48 **CAWS**	one hundred.			
1225:49 **CAWS**	fifty.			
1225:50 **CAWS**	forty.			
1225:51 **CAWS**	thirty.			

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1225:51 **CAWS**	twenty.			
1225:52 **CAWS**	ten.			
1225:53 **CAM**	[sound of thump]			
1225:55 **CAM**	[sound of squeak]			
1225:55 **CAM**	[sound of whirring]			
1225:56 **HOT-2**	wow.			
1226:05 **CAM**	[sound of increasing background noise, similar to increased engine RPM]			
1226:08 **CAM**	[sound of rumbling, increasing in volume]			
1226:08 **HOT-2**	*.			

INTRA-COCKPIT COMMUNICATION		43 of 45	AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1226:12 **CAM-1**	***.			
1226:17 **HOT-2**	oh #.			
1226:21 **CAM-1**	ugh. jesus christ.			
1226:23 **CAM-3**	nose wheel steering.			
1226:24 **CAWS**	[sound of tone]			
1226:24 **CAM**	[sound of decreased background noise]			
1226:25 **CAM-1**	here we go.			
1226:25 **CAM**	[sound of thump]			
1226:25 **CAWS**	…landing gear.			

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1226:25 **CAM**	[sound of thumps, continue for five seconds]			
1226:27 **CAWS**	[sound of tri-tone]			
1226:29 **CAWS**	[sound of tone]…			
1226:30 **CAM**	[sound of two buzzes]			
1226:30 **CAM**	[sound of double-click]			
1226:31 **CAWS**	…landing gear.			
1226:31 **HOT-2**	ah #.			
1226:32 **CAWS**	[sound of tone] landing gear.			
1226:35 **CAWS**	[sound of tone]…			

INTRA-COCKPIT COMMUNICATION			AIRCRAFT-TO-GROUND COMMUNICATION	
Time (CST) SOURCE	CONTENT		Time (CST) SOURCE	CONTENT
1226:35 **HOT-2**	oh my god.			
1226:36 **CAM**	[sound of double-click]			
1226:36 **CAM-?**	shut 'em down. [source is 1 or 3]			
1226:37 **CAWS**	…landing gear.			
1226:38 **CAWS**	[sound of tone]…			
1226:39 **CAM**	[sound of clicks]			
1226:39 **CAWS**	…landing gear.			
1226:41 **CAWS**	[sound of tone]			
1226:41 **END OF TRANSCRIPT** **END OF RECORDING**				

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